

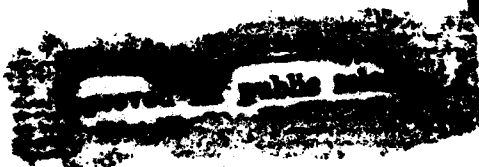
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Overhead Allocation and Incentives for Cost Minimization in Defense Procurement

William P. Rogerson

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PREFACE

This report is part of a larger project on the economics of defense acquisition. It was sponsored by the Assistant Secretary of Defense (Program Analysis and Evaluation) and was carried out in the Acquisition and Support Policy Program of RAND's National Defense Research Institute, a federally funded research and development center supported by the Office of the Secretary of Defense and the Joint Staff.

The publication should be of interest to researchers and policymakers who are concerned about the effects of profit policy and cost-accounting regulations on business incentives, system costs, and contractor profits.

A shorter version of this report has appeared in *The Accounting Review*, a publication of the American Accounting Association, Vol. 67, October 1992, pp. 671-690. Publication is made possible with permission from *The Accounting Review*.

SUMMARY

Defense firms typically produce a large number of products and it is often difficult to keep track of the cost of producing each separate product. Much as the rest of American industry, defense firms have typically dealt with this difficulty by directly charging a small fraction of their costs. The remaining costs are grouped together in overhead pools and allocated across products usually in proportion to direct labor use.

The purpose of this report is to explain a problem that this creates for the defense procurement process. The problem occurs because the responsiveness of price to accounting cost varies between products. A purely commercial product is sold at a competitive market price determined independently of accounting cost. For defense products, the Department of Defense's nominal goal is to pay a price equal to the "true" expected cost. However, in reality, the negotiated price is likely to be affected by other factors as well. In particular, in cases where closer substitutes exist or where an alternative source might not be prohibitively expensive, the potential cost of these alternatives also plays a role. A typical defense firm is likely to have both well-funded sole source procurements, where price is extremely responsive to cost, and commercial products or competitive defense procurements, where price is much less responsive to cost.

Of course, the firm will prefer to allocate overhead to contracts where price is most responsive to accounting cost. Because overhead is allocated in proportion to direct labor use, the firm can attempt to influence the allocation of overhead by distorting its direct labor usage. Therefore, the major conclusion of this study is that current overhead allocation methods create incentives for firms to systematically overuse direct labor on contracts where they believe that price will be fairly responsive to accounting cost and to underuse direct labor on contracts where they believe that price will be fairly unresponsive to accounting cost.

A firm may respond to this incentive by engaging in pure waste, i.e., by simply employing excess direct labor on contracts that it would like to shift overhead onto. However, a firm may also respond by distorting its input substitution decisions. It would substitute toward (away from) direct labor on contracts that it would like to shift overhead onto (away from). Two major types of input substitutes exist—capital and material. The level of automation clearly affects the capi-

tal/labor mix. The firm can essentially substitute away from material and toward labor by reducing its level of subcontracting and bringing more business in-house. Therefore, this report predicts that production of products whose prices are fairly responsive to accounting cost will exhibit too little automation and too much in-house production. The reverse will be true for products whose prices are fairly unresponsive to accounting cost.

A rough estimate of the magnitude of this incentive effect is calculated by using data on the cost pools of four major aerospace contractors. Given the average overhead rates of these contractors, it is shown that incurring \$1.00 of extra direct labor on a well-funded sole source procurement generates between \$1.20 and \$1.44 of extra revenue.

ACKNOWLEDGMENTS

This report and the project of which it is a part owe a great debt to David McNicol. The project came into being largely because of his conviction that modern economic analysis could make important contributions to the analysis of defense procurement. I would like to thank him and his staff members, Gary Bliss and Craig College, for their help, encouragement, and careful readings of numerous drafts over the life of the project.

I would also like to thank numerous colleagues at RAND. Chief among them is James Dertouzos. James was the ideal project leader. He allowed me great freedom to pursue the ideas that I felt were most interesting. We spent untold hours in debate and discussion of issues in defense procurement and all of my work in this project has benefited immensely from this interaction. I would like to thank Anthony Bower and Glenn Gotz for their careful reviews of a draft of this report.

I would also like to thank Kathleen Hagerty and James McCullough for extremely helpful discussions and comments.

Finally, special thanks to Florence Stein for outstanding typing assistance.

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1. INTRODUCTION

Defense firms typically produce a large number of products. The purpose of this report is to explain how two features of the current regulatory process create a significant incentive for these multiple-product firms to purposely choose inefficient production methods. Although this incentive appears to be very large, it has not been previously recognized or understood in the procurement literature.

First, the marginal impact of accounting cost on price varies significantly among products. Prices for a defense firm's products are set according to a unique process that combines elements of both competition and cost-based regulation. Defense firms typically produce some purely commercial products and prices for these products are competitively determined. Aside from standard off-the-shelf items such as combat boots, the prices of most defense products are nominally cost-based. At the beginning of any procurement the firm is required by law to submit detailed estimates of its anticipated costs of production. The firm is required to certify, subject to both criminal and civil penalties, that these estimates are current, accurate, and complete.¹ The Department of Defense (DoD) devotes vast resources to auditing the firm's actual costs both to verify the accuracy of previous projections and to assess the reasonableness of future projections. The DoD's nominal goal is to pay a price equal to the "true" expected cost. In reality, the negotiated price is likely to be affected by other factors as well. In particular, when a close substitute exists or when an alternative source is not prohibitively expensive, the potential cost of these alternatives plays a role. The important consequence of this is that the negotiated price will not necessarily decline or rise by a full dollar when the cost of production declines or rises by a dollar. In more competitive procurements, where the cost of alternatives plays a stronger role, changes in projected accounting costs are less important. The typical defense firm is likely to have both well-funded sole-source procurements, where price is extremely responsive to cost, and commercial products or competitive defense procurements, where price is much less responsive to cost.

The second feature of the regulatory process concerns the method that defense firms are allowed to use to calculate the cost of each

¹This certification is required by the Truth-in-Negotiations Act. See Oyer and Mateer (1987).

product.² The difficulty that almost any multiple-product firm must face is that it is difficult or even impossible to directly assign all costs incurred to individual products. Defense firms have been allowed to deal with this difficulty by adopting the same types of accounting systems as most purely commercial American manufacturing firms have traditionally used. Only a fairly small fraction of costs are directly charged to products. The remaining costs are grouped together into overhead pools and allocated across products usually in proportion to directly charged labor use. The historic rationale for this procedure has been the intuition that a variety of input costs probably vary proportionately with direct labor use.

These two features create the following incentive problem. Given the first feature, the firm would typically like to be able to shift costs between products. That is, it would like to be able to assign more of its costs to well-funded sole-source procurements instead of to more competitive procurements or commercial products. The second feature provides a method for accomplishing this. Suppose that the firm burns a dollar and can claim it was a direct labor expense on a particular contract. The result will be that more overhead is allocated to the contract in question and less to all other contracts.

A simple example may help clarify the nature of this incentive. Suppose that the firm produces only two products—a defense product and a commercial product. Suppose that the firm incurs \$100 of direct labor on each product. Furthermore, overhead costs total \$300 and are allocated according to direct labor. Therefore, the fully allocated cost of each product is \$250. The commercial product is sold at a fixed market price independent of any accounting calculations. However, the defense product's price is set to be exactly equal to its accounting cost.

Now suppose that the firm burns \$100 and claims that it is a direct labor expense for the defense product. The defense product now uses two-thirds of the total direct labor and thus is allocated two-thirds of the overhead. Therefore, its fully allocated cost is \$400 (\$200 of direct labor plus \$200 of overhead). As a consequence, the price of the defense product rises to \$400. So, by burning \$100 the firm receives increased revenue of \$150. This is because the \$100 of direct labor caused \$50 of overhead to be shifted onto the defense contract.

Five remarks will now be noted about this incentive effect. First, the potential size of the effect is enormous. This report will show that

²Appendix A gives a brief overview of the nature of these regulations.

typical overhead rates and cost-sensitivity differentials actually generate incentives to incur pure waste about as large as described in the example above. By burning \$1, a firm might typically generate a return of \$1.20 to \$1.50 (i.e., the above example generates a figure on the high side of the plausible range).

Second, the effect is *not* due to cost plus a percentage of cost (CPPC) pricing. CPPC pricing is said to occur when a defense product's price is set equal to its fully allocated accounting cost plus a percentage of this cost. In the example above, CPPC pricing was explicitly ruled out. This report shows that the same effect as CPPC pricing occurs through overhead shifting even if there is no CPPC pricing. In fact, this effect will be called a "CPPC effect" here. That is, if by spending \$1 the firm receives $(\$1 + \alpha)$ in revenue, it will be said that there is a CPPC effect equal to $\alpha \times 100$ percent. Thus in the example above, there was a 50 percent CPPC effect.

It is commonly thought that CPPC pricing does occur in defense procurement,³ because the price of defense products includes a term labeled as "profit" which tends to equal about 10–15 percent of total price. However, in previous work (Rogerson, 1991a) I have argued that most "profit" consists of payments for true economic costs of production that are not formally labeled as costs (facilities capital, working capital, risk-bearing). I conclude that there is perhaps a CPPC effect equal to 2 percent or less arising from the profit calculation. The important point is that the magnitude of the CPPC effect identified in this report of perhaps 20–50 percent dwarfs any possible effect occurring from CPPC pricing.

Many analysts of the procurement process have correctly observed that defense firms often seem to behave as though increased costs on defense contracts actually raise their profits. In the absence of any other possible explanation, they perhaps quite reasonably have concluded that CPPC pricing must be the source of the problem. This report identifies another totally separate source of this effect which, in all likelihood, is much more important.

³One can distinguish between two types of CPPC pricing. *Ex post* CPPC pricing occurs when a cost reimbursement contract specifies that a firm's payment will equal its *ex post* cost plus a percentage of *ex post* cost. Defense regulations prohibit this type of contract. On a fixed price contract, *ex ante* CPPC pricing occurs when price is set equal to *ex ante* (expected) cost plus a percentage of *ex ante* cost. On a cost reimbursement contract, *ex ante* CPPC pricing occurs when the firm is paid a fee calculated as a percentage of *ex ante* cost in addition to being fully reimbursed for its *ex post* costs. *Ex ante* CPPC pricing is not prohibited by procurement regulations. This report will always use the term CPPC pricing to mean *ex ante* CPPC pricing.

Third, it is important to note that the firm makes money from *anticipated* cost changes. In this report the firm can be viewed as truthfully projecting all of its costs to the DoD. It does *not* make money by projecting that costs will be high (to get a high price) and then actually having low costs. All of the costs here can be viewed as being fully anticipated by the DoD; i.e., the firm actually spends all of the money that is charged as a cost. The profit occurs through shifting the assignment of these costs. The importance of this point is that auditing is very poorly equipped to deal with this type of behavior. Although it is fairly good at determining whether the firm actually spent as much as it projected it would, it is fairly poor at determining whether any expenditure that actually occurred was necessary.

Fourth, although the example above was one where the firm wanted to shift overhead from commercial to defense business, the existence of commercial business is not required to generate this effect. The effect will occur whenever the prices of a firm's products exhibit differential sensitivities to cost. Within its defense business such differentials will generally exist. For example, a dollar of increased cost will probably generate nearly a full dollar of increased revenue on a well-funded sole-source program or on the follow-on spare-parts contracts. However, it may generate much less revenue in a competitive dual-sourcing situation or on a contract that many firms are competing for (perhaps because it is the first contract in a long program and the winner of the first contract will be in a sole-source position for all follow-on contracts).

Fifth, incentives will be created for more subtle types of cost increases than mere waste. The general incentive for firms will be to increase direct labor usage on products with cost-sensitive revenue and to decrease direct labor usage on products with cost-insensitive revenue. This can be accomplished by input substitution as well as pure waste. That is, the firm can substitute toward more direct labor on products with cost-sensitive revenue and toward less direct labor on products with cost-insensitive revenue. Two major types of input substitutes exist. The first is capital. Thus, we would expect the firm to purposely undercapitalize production of products with cost-sensitive revenues and to overcapitalize production of products with cost-insensitive revenues. The second possible input substitute is material. The idea here is slightly more subtle. For many subcomponents of a weapon, a firm has the potential option of subcontracting production to another firm or making the component in-house. Subcontracting will result in higher direct material costs for the firm but lower direct labor costs. Thus, engaging in more in-house production is essentially a way of substituting toward direct labor and away from direct mate-

rial. In particular, then, we would expect the firm to purposely engage in too much in-house production for its products with cost-sensitive revenue and too much subcontracting for its products with cost-insensitive revenue. If we translate "cost-sensitive" as "defense products" and "cost-insensitive" as "commercial products" we have the following predictions. Defense firms will purposely undercapitalize their production of defense products and keep too much production in-house. They will also purposely overcapitalize their production of commercial products and keep too little production in-house.

This incentive to distort the input substitution choice is important for a number of reasons, the most important being that the incentives to increase cost are not confined merely to "padding" direct labor. Almost all of the firm's choices regarding production technologies can be affected. Furthermore, both cost-sensitive as well as cost-insensitive products are affected unlike the case of pure waste where "negative" waste is not possible. Finally, auditing is probably even worse at determining whether the optimal input mix has been employed than whether direct labor has been padded.

There is no existing procurement literature of which I am aware that identifies the incentive problem described in this report. However, Braeutigam and Panzar (1989), Brennan (1990), and Sweeney (1982) have made the same general point in the context of models of public utility regulation, where the utility has some purely commercial business. They show that, depending upon how costs are allocated, the firm may have an incentive to distort its output or input decisions to shift overhead to the regulated sector. However, none of these papers specifically analyze allocation schemes based on direct labor or any other input base. Braeutigam and Panzar (1989) and Sweeney (1982) consider allocation schemes based on units of output under the assumption that comparable units of output exist across different products. Brennan (1990) considers allocation schemes where each product is allocated a fixed, invariant share of overhead. Thus, essentially all of the predictions of this report regarding the particular sorts of input distortions one would expect to see in defense procurement are new. Furthermore, on a technical level, the model of this report is also somewhat different because it considers a multiple-product case where products are not necessarily either perfectly competitive or perfectly regulated and the level of competitiveness varies from product to product.

The report is organized as follows. Section 2 presents the formal model. Section 3 begins the formal analysis by calculating the marginal effect on profit from various input distortions. Section 4

then completes the formal analysis by calculating equilibrium input distortions. Section 5 attempts to assess the empirical significance of these incentive effects by actually estimating the marginal effect of input distortions on profit for a typical defense firm. Section 6 discusses a number of the results in more detail and Sec. 7 outlines possible policy approaches. Finally, Sec. 8 briefly considers a related incentive issue. Namely, it may be that the overhead allocation process also distorts internal DoD decisions.

2. THE MODEL

INTRODUCTION

The model will be presented in two subsections. First, I will describe how revenues are determined given the vector of fully allocated costs. Then, I will describe how fully allocated costs are determined by the accounting system of the firm.

REVENUES

Suppose that the firm is producing n products, indexed by $i \in \{1, \dots, n\}$. Some of these products are sold solely to the DoD and some may be commercial. For expositional simplicity it will be assumed that a fixed quantity of each product is produced.

Let C_i denote the fully allocated cost of product i .¹ As explained in the Introduction, this report focuses on *anticipated* cost changes. Consistent with this, it will be assumed that the DoD knows C_i . The existence of cost uncertainty will be ignored, since it is not required to build a model capturing the desired effects. Thus C_i is a certain value. Let r_i denote the revenue from product i . Assume that the revenue from each product is determined by some twice continuously differentiable function,

$$r_i = \phi_i(C_i) , \quad (2.1)$$

where

$$0 \leq \phi'_i(C_i) \quad (2.2)$$

and

$$\phi''_i(C_i) \leq 1 . \quad (2.3)$$

¹Interpret C_i as being *all* economic costs, including the cost of risk-bearing and capital.

Assumption (2.2) simply requires that revenue be weakly increasing in accounting cost. Assumption (2.3) rules out CPPC pricing. As explained in the Introduction, the point of this report is to show that a CPPC effect exists even when there is no CPPC pricing.

The derivative of revenue with respect to cost, $\phi_i'(C_i)$, is a measure of the cost-sensitivity of the revenue of product i . The basic explanation of why $\phi_i'(C_i)$ varies among products was presented in the Introduction. Although the regulations nominally require that price be set exactly equal to anticipated cost, in reality the relative bargaining strength of the two parties also affects price. In particular, cost will become less important in situations where the procurement is more competitive. Two types of competitive pressures exist. Intracontract competition occurs when a number of firms compete for the same contract. The term sole source (multiple source) will often be used to describe contracts facing low (high) levels of intracontract competition. Intercontract competition occurs when a given contract must compete for funding with other possible uses of the funds. Intercontract competition can exist at many different levels. Two weapons systems might be viewed as substitutes for performing the same narrowly defined military mission. Alternatively, two weapons systems performing very different missions might be viewed as substitutes in producing defense. At the broadest level, defense and non-defense programs substitute in producing social welfare. Strong intercontract competition at any of the above levels will manifest itself in the form of tight budgets and funding constraints. Thus the term well funded (poorly funded) will often be used to describe contracts facing low (high) levels of intercontract competition.

All of the discussion above has been cast as though all contracts were fixed price. However, this was simply for expositional convenience. The modeling assumption that revenues are a function of accounting costs as captured in Eq. (2.1) is also appropriate to describe the situation occurring under cost-type contracts. An important point to note in interpreting this model is that the strength of competition rather than contract type will be the primary determinant of a contract's cost-sensitivity. In particular, cost-type contracts will not necessarily be more cost-sensitive than fixed-price contracts. It is true that a cost-reimbursement contract explicitly requires that *ex post* revenues move dollar for dollar with *ex post* costs. However, it also includes a clause specifying the maximum amount of cost the firm can incur and be reimbursed for. In many cases, defense firms purposely accept cost-type contracts that are not funded (and will not be funded) up to the level of the expenditures they truly expect to incur. In these cases, the marginal effect of cost changes on revenue may well be less

than one and perhaps even equal to zero. This is because *ex ante* negotiations over the ceiling level and *ex post* negotiations over incremental funding for overruns will in fact determine the firm's revenues. For example, many people have argued that defense firms as a standard operating procedure lose money on cost-type R&D contracts in the early stages of a program to be selected as the sole producer of the weapon and (it is hoped) earn large profits when negotiating fixed-price production contracts in a sole-source environment.²

FULLY ALLOCATED COSTS

This subsection will formally model the cost-accounting system that the firm will be assumed to use. To clearly illustrate the effects in the simplest possible model, it will be assumed that all overhead is allocated in proportion to direct labor usage. To the extent that overhead is allocated according to direct labor, the effects identified in this report will continue to exist in more complex environments with multiple overhead pools and where not all overhead is necessarily allocated according to direct labor.

The cost-accounting system directly assigns some labor and material to individual contracts. Let L_i and M_i denote, respectively, the dollar value of direct labor and direct material for contract i . All other inputs are called indirect costs or overhead. Let V denote the total dollar value of overhead. Assume that some of the overhead costs are in fact incurred for only one product. They are not directly assigned to contracts because it would be expensive or perhaps impossible to do so objectively. Let Z_i denote the costs for product i that are included in overhead. Finally, let J denote joint costs that cannot be assigned to any particular contract, even in principle. Total overhead is the sum of these components.

$$V = \sum_{i=1}^n Z_i + J . \quad (2.4)$$

Overhead is allocated to contracts according to direct labor usage. Thus, the overhead allocated to product i , denoted by V_i , is given by

²See Rogerson (1989 and 1991b) for an economic analysis of this phenomenon.

$$V_i = \frac{L_i V}{\sum_{k=1}^n L_k} . \quad (2.5)$$

Let R^M denote the overhead rate which is defined to be the ratio of overhead to direct labor.

$$R^M = \frac{V}{\sum_{k=1}^n L_k} . \quad (2.6)$$

We can view each dollar of direct labor as attracting R^M dollars of overhead. Consistent with intuition, Eq. (2.5) can be rewritten as

$$V_i = R^M L_i . \quad (2.7)$$

The total cost of product i , denoted by C_i , is the sum of all direct and indirect costs. It is given by

$$C_i = (1 + R^M) L_i + M_i \quad (2.8)$$

or, equivalently, by

$$C_i = L_i + M_i + \left(\frac{L_i}{\sum_{k=1}^n L_k} \right) \left(\sum_{k=1}^n Z_k + J \right) . \quad (2.9)$$

Finally, it will be useful to let a variable without the subscript i denote the vector of corresponding variables for each product—i.e.,

$$C = (C_1, \dots, C_n) , \quad (2.10)$$

$$L = (L_1, \dots, L_n) , \quad (2.11)$$

etc.

3. FORMAL ANALYSIS OF THE MARGINAL EFFECT OF INPUT CHOICE ON PROFIT

INTRODUCTION

In Secs. 3 and 4, the values of the cost pools (i.e., L, M, Z, and J) are viewed as choice variables for the firm. Both the case where the firm can simply incur waste and the case where the firm substitutes between inputs will be considered. The firm's revenues for product i are determined by the function $\phi_i(C_i)$, as described in Sec. 2. Therefore, the firm's profits given its input choices are described by the function

$$\Gamma(L, M, Z, J) = \sum_{j=1}^n \phi_j(C_j) - C_j \quad (3.1)$$

where C_j is determined by Eq. (2.9).

Section 4 will actually solve for the profit-maximizing input choices of the firm. This section will perform a more basic calculation. It will calculate the marginal effect on profit from various types of waste or input substitutions. This is useful for a number of reasons. First, it will provide an extremely clear and simple explanation of the cause and nature of the incentive effects acting on the firm. Second, the formulas developed here will provide a useful method for calculating the magnitude of the incentive effects that actually exist. This calculation will be done in Sec. 5.

The fundamental theoretical result is presented below. Then, it is applied to the various cases of interest.

THE FUNDAMENTAL RESULT

It will be useful to first define one more piece of notation. Let A denote the weighted average cost-sensitivity of all the firm's contracts where the weights equal the share of direct labor used by each contract.

$$A = \sum_{i=1}^n \left(\frac{L_i}{\sum_{k=1}^n L_k} \right) \phi'_i(C_i) . \quad (3.2)$$

Just as for R^M and C_i , A will be viewed a function of the input choices, L , M , Z , and J . However, for expositional convenience this functional dependence will not be explicitly indicated in the notation.

Proposition 1 presents the derivative of profit with respect to the variables L_i , M_i , Z_i , and J . This is the basic technical result that will be used in subsequent subsections. Since the proofs simply involve straightforward differentiation of Eq. (3.1), they will not be presented.

Proposition 1:

$$\frac{\partial \Gamma}{\partial M_i} = \phi'_i(C_i) - 1 \quad (3.3)$$

$$\frac{\partial \Gamma}{\partial Z_i} = A - 1 \quad (3.4)$$

$$\frac{\partial \Gamma}{\partial J} = A - 1 \quad (3.5)$$

$$\frac{\partial \Gamma}{\partial L_i} = R^M [\phi'_i(C_i) - A] + [\phi'_i(C_i) - 1] . \quad (3.6)$$

Extremely intuitive explanations exist for all four formulas. First consider Eq. (3.3). The only effect of increasing direct material by \$1 is that the cost of contract i goes up by \$1. Revenues rise by $\phi'_i(C_i)$. The effect on profit is the change in revenues minus the change in cost that is given by Eq. (3.3). Now consider Eqs. (3.4) and (3.5) together. Suppose that overhead increases by \$1. (It is irrelevant whether it is Z_i or J , since both are allocated in the same fashion.) The change in profit then equals the change in revenues minus \$1 (since \$1 is the change in cost). The change in revenue will now be calculated. The increased dollar of overhead is allocated to all con-

tracts in proportion to direct labor cost. Therefore contract i experiences a change in cost of

$$\frac{L_i}{\sum_{k=1}^n L_k} \quad (3.7)$$

dollars. Therefore, revenue on contract i goes up by

$$\frac{L_i}{\sum_{k=1}^n L_k} \phi'_i(C_i) \quad (3.8)$$

dollars. The total revenue change is the sum over i of the terms in Eq. (3.8). This by definition is A , the weighted average cost-sensitivity. Therefore, in summary, a dollar increase in overhead causes revenues to increase by A dollars. The change in profit thus equals $A - 1$ dollars, which is Eqs. (3.4) and (3.5).

Although expression (3.6) is more complicated, the insights necessary to explain it have essentially been developed above. When direct labor on contract i increases by \$1 there are two effects. The first effect is that the cost of contract i goes up by \$1 because all of the dollar increase is directly assigned to contract i . Just as for Eq. (3.3), this causes a profit change of

$$\phi'_i(C_i) - 1, \quad (3.9)$$

which is the second term of Eq. (3.6). The second effect is that the extra dollar of direct labor attracts R^M dollars of overhead to contract i . Suppose that \$1 of overhead is shifted to contract i . This means that \$1 of overhead is taken away from all contracts. By the analysis of Eqs. (3.4) and (3.5), this causes revenue to decline by A dollars. Since the dollar of overhead is now assigned to contract i , revenue increases by $\phi'_i(C_i)$. Therefore, the net change in revenue when \$1 of overhead is shifted to contract i is

$$\phi'_i(C_i) - A. \quad (3.10)$$

However, the dollar of direct labor attracts R^M dollars of overhead. Thus profit changes by

$$R^M[\phi_i'(C_i) - A] . \quad (3.11)$$

This is the first term of Eq. (3.6).

PURE WASTE

Suppose that the firm could burn a dollar and have it be labeled as either a direct labor expense or direct material expense on contract i or as an overhead expense. Would it want to do this and why? This is the question addressed in this subsection.

First, consider the question of direct material or overhead waste. The firm will never have an incentive to engage in this type of waste. This is because revenues are assumed to increase by at most \$1 when costs go up by \$1. Thus, the best result that could possibly occur is that the firm's profits would be unchanged. In general, of course, revenues will go up by less than \$1 and therefore profits will actually decline. In conclusion, the assumption that there is no CPPC pricing (i.e., $\phi_i'(C_i) \leq 1$ for every i) means that the firm has no incentive to incur pure waste of overhead or any direct input that is not an allocation base.

Now the more interesting question of direct labor will be turned to. Just as for direct material, the dollar of direct labor will be only partially reimbursed through revenues and the decrease in profits is given by

$$\phi_i'(C_i) - 1 . \quad (3.12)$$

However, now there is an extra effect because of overhead shifting. In particular, if contract i is more cost-sensitive than the weighted average of the firm's contracts, then the firm can increase its revenues by shifting overhead to contract i where it will be more fully reimbursed. If this effect is big enough, it may overwhelm the other effect and the firm will find it profitable to incur pure waste of direct labor for contract i .

Three factors determine the magnitude of this effect. These are $\phi_i'(C_i)$, R^M , and $[\phi_i'(C_i) - A]$. Each of these will be discussed in turn. First consider $\phi_i'(C_i)$, the cost-sensitivity of contract i . As contract i becomes more cost-sensitive, the penalty for incurring a dollar of waste grows smaller because a larger fraction of it will be reimbursed. For a perfectly cost-sensitive contract there is no penalty at all.

Now consider the overhead rate, R^M . The overhead shifting effect is larger if R^M is larger because \$1 of direct labor attracts more overhead. In particular, then, the incentive to incur direct waste on contracts of above-average cost-sensitivity grows larger as the overhead rate grows larger.

Finally, consider the differential cost-sensitivity between contract i and the average contract, $\phi'_i(C_i) - A$. This term must be positive for the firm to want to shift overhead to contract i . As it becomes more positive, the incentive to shift overhead through incurring direct labor waste grows larger. This is because contract i will reimburse relatively more of the overhead than would have occurred if the overhead had been allocated to all contracts.

INPUT SUBSTITUTION: GENERAL

The general idea illustrated by the calculations above is that the firm would like to increase direct labor usage on cost-sensitive contracts and decrease direct labor usage on cost-insensitive contracts to shift overhead toward contracts that will reimburse a greater share of it. Incurring pure waste labeled as direct labor is one method to accomplish this. However substituting between direct labor and some other input is obviously another way. This subsection will develop the general formula for calculating the impact on profit from substitutions between labor and any combination of other inputs. Then, following subsections will consider particular substitution problems using the general formula derived here.

The general input substitution problem will now be described. It will be assumed that the firm can substitute between L_i , M_i , and Z_i . View L_i as the firm's choice variable. Then assume that the required amounts of the other two inputs are given by the two differentiable functions

$$Z_i = g_i(L_i) \quad (3.13)$$

and

$$M_i = h_i(L_i) . \quad (3.14)$$

Let $\pi(L)$ denote the firm's profits given its choice of labor inputs and given the resulting choice of Z and M required by Eqs. (3.13) and (3.14). (View J as fixed at some level for this entire analysis.)

Formally, the function $\pi(L)$ is given by Eq. (3.1) where Z_i and M_i are determined by Eqs. (3.13) and (3.14).

Proposition 2 presents the marginal effect on profit of a change in direct labor (with adjustment of other inputs).

Proposition 2:

$$\begin{aligned} \frac{\partial \pi}{\partial L_i} = & [R^M - g'_i(L_i)] [\phi'_i(C_i) - A] \\ & + [1 + h'_i(L_i) + g'_i(L_i)] [\phi'_i(C_i) - 1] . \end{aligned} \quad (3.15)$$

Proof:

By the chain rule,

$$\frac{\partial \pi}{\partial L_i} = \frac{\partial \Gamma}{\partial L_i} + h'_i(L_i) \frac{\partial \Gamma}{\partial M_i} + g'_i(L_i) \frac{\partial \Gamma}{\partial Z_i} . \quad (3.16)$$

The result now follows immediately by substituting in the results from Proposition 1. Q.E.D.

The calculation of Eq. (3.15) is a relatively trivial application of Proposition 1 as explained in the proof. An increase in L_i of \$1 causes M_i to change by $h'_i(L_i)$ dollars and Z_i to change by $g'_i(L_i)$ dollars. The impact of each of these three effects can be calculated from Proposition 1. Then $\partial \pi / \partial L_i$ is simply the sum of these three effects.

Expression (3.15) will not be further explained in general. Further analysis will be conducted in the context of more specific types of input substitution problems below. However, before doing this, one general methodological point applying to all of these analyses will be made.

In general, when the firm substitutes between labor and other inputs two factors affect its profits. The first is simply cost efficiency. That is, all other things being equal, if spending \$1 on labor will save \$10 of some other input, the firm will be inclined to do this. The second factor is the effect of the input substitution on cost allocation, which in turn affects profits.

The goal in the subsections below is to analyze the nature of the incentives operating on the firm as a result of the second factor.

Formally, the way to isolate this second factor is to assume that the firm is currently making an optimal input choice from the standpoint of cost minimization and to then measure the marginal effect of increased labor usage (with a corresponding decrease in other input usage) on profit. To put this another way, the upcoming subsections will measure the marginal effect on profit of using \$1 more of direct labor when this causes \$1 less of other inputs to be used. Thus, there is no cost-efficiency effect and the entire change in profit must be due to cost-allocation effects.

LABOR-MATERIAL SUBSTITUTION

In this subsection it will be assumed that

$$g'_i(L_i) = 0 \quad (3.17)$$

for every L_i . Thus, only substitution between labor and material is considered. As explained above, it will also be assumed that \$1 of increased labor generates \$1 of decreased material to focus on cost-allocation effects. Formally, this is given by the assumption that

$$h'_i(L_i) = -1 \quad (3.18)$$

at the value of L_i for which the derivative is being evaluated.

Substitution of Eqs. (3.17) and (3.18) into Eq. (3.15) yields

$$\frac{\partial \pi}{\partial L_i} = R^M [\phi'_i(C_i) - A] \quad (3.19)$$

Recall that Eq. (3.6) gives the marginal effect on profit of a dollar of pure labor waste. A comparison of Eqs. (3.6) and (3.19) reveals that Eq. (3.19) equals the first term of Eq. (3.6). The reason for this is straightforward. Just as for the pure-waste case, spending an additional dollar on direct labor causes R^M dollars of overhead to shift to contract i . However, this is now the only effect, because the increased dollar of direct labor expenditure is coupled with a decreased dollar of direct material expenditure. Thus, there is no change in direct cost.

Therefore, the firm will in general have the incentive to distort direct labor usage on *all* of its contracts, the only exception being contracts that are of precisely average cost-sensitivity. It will want to use too much labor on contracts that are of above-average cost-sensitivity and

use too little direct labor on contracts that are of below-average cost-sensitivity. Its incentives to do this will be greater if the overhead rate is greater and if the variation in cost-sensitivity among contracts is greater.

One final comment about the comparison between this case and the pure-waste case should be noted. Expression (3.19) is always greater than or equal to Eq. (3.6) for the obvious reason. Profits in general rise if direct material usage decreases. Therefore, using a dollar of productive labor to replace a dollar of material is more profitable than simply burning the dollar. This general principle will apply to almost all input substitution cases. It will generally always be more profitable to increase direct labor in such a way that other inputs can be reduced rather than to simply burn money and call it direct labor. This suggests that the firm will never have the incentive to engage in pure waste whenever input substitution is possible; this formal result will be demonstrated in Sec. 4.

However, the pure-waste model is still interesting for two reasons. First, over short enough time horizons, changing technologies to effect an input substitution may be difficult. Thus, pure waste may still be an important short-run phenomenon. Second, the pure-waste model very clearly illustrates the basic incentive structure created by overhead allocation based on direct input usage and it is thus of analytic value.

LABOR-OVERHEAD SUBSTITUTION

In this subsection it will be assumed that

$$h'_i(L_i)=0 \quad (3.20)$$

for every L_i . Thus, only substitution between overhead and labor will be considered. As explained above, it will also be assumed that \$1 of increased labor generates \$1 of decreased overhead to focus on cost-allocation effects. Formally, this is given by the assumption that

$$g'_i(L_i)=-1 \quad (3.21)$$

at the value of L_i for which the derivative is being evaluated.

Substitution of Eqs. (3.20) and (3.21) into Eq. (3.15) yields

$$\frac{\partial \pi}{\partial L_i} = (1 + R^M) [\phi'_i(C_i) - A] . \quad (3.22)$$

A comparison of Eqs. (3.19) and (3.22) reveals that the term R^M in Eq. (3.19) has been replaced by the term $1 + R^M$ in Eq. (3.22). The reason for this is very simple. When the firm spends \$1 more on L_i and \$1 less on Z_i it is directly transferring \$1 of overhead to contract i . This occurs in addition to the fact that the dollar of direct labor attracts R^M dollars of overhead. For the labor-material substitution case only R^M dollars of overhead are transferred. For the labor-overhead substitution case, $1 + R^M$ dollars are transferred.

The formulas for the labor-material case and labor-overhead case are very similar and all the comments made for the labor-material case apply here as well and will not be repeated. However, some new points focusing on the difference between the formulas will be made.

It will be useful to label the two incentive effects described above. Rewrite Eq. (3.22) as

$$\frac{\partial \pi}{\partial L_i} = R^M [\phi'_i(C_i) - A] + [\phi'_i(C_i) - A] . \quad (3.23)$$

The first term of Eq. (3.23) corresponds to the incentive effect identified for the pure-waste and labor-material substitution cases. It will be called the "allocation base" incentive to distort labor choice. The reason for this name is that the incentive to distort direct labor occurs because it is the allocation base for overhead. The second term of Eq. (3.23) corresponds to the extra incentive that applies only to the labor-overhead case. It will be called the "direct" incentive to distort labor choice. The reason for this name is that the incentive to distort direct labor occurs because the substitution directly shifts costs between overhead and contract i .

Three points should be noted about the direct incentive to distort labor choice. First, the incentive to distort the labor-overhead choice will be greater than that to distort the labor-material choice because of this extra effect. In fact, it will be argued in Sec. 5 that a typical value for R^M is approximately 1. Thus, the incentive to distort the labor-overhead choice might typically be approximately twice as large as that to distort the labor-material choice.

Second, the direct incentive affects all of the firm's direct inputs and not only those used as an allocation base. In particular, in this report's model, the firm would also have an incentive to distort the ma-

terial-overhead choice in the same fashion as the labor-overhead choice.

Third, different policy approaches might be required to deal with this extra effect. In particular, even if overhead were allocated according to some totally nonmanipulable criterion (e.g., an equal share to each contract), the direct incentive effect would still exist.

SUBCONTRACTING

As explained in the Introduction, the choice of the level of subcontracting can be viewed as an input substitution choice. Increasing the level of in-house production clearly increases direct labor, L_i , and decreases material, M_i . If these were the only two effects, then the analysis above would apply. However, a third effect is likely to occur as well, which complicates the analysis. This is that the use of some inputs classified as overhead will also likely increase. Formally, this means that Z_i will increase.

Formally, then, view L_i as the choice variable of the firm. Higher values of L_i correspond to increased levels of in-house production, i.e., decreased levels of subcontracting. Consistent with the description in the above paragraph, assume that

$$g'_i(L_i) > 0 \quad (3.24)$$

and

$$h'_i(L_i) < 0 \quad (3.25)$$

for every L_i . As usual, to focus on cost-allocation effects, it will be assumed that \$1 of increased labor use generates a net decrease of \$1 of other input use. Formally, this is given by the assumption that

$$h'_i(L_i) + g'_i(L_i) = -1. \quad (3.26)$$

Substitution of Eq. (3.26) into Eq. (3.15) yields

$$\frac{\partial \pi}{\partial L_i} = [R^M - g'_i(L_i)][\phi'_i(C_i) - A]. \quad (3.27)$$

Formula (3.27) cannot in general be signed. This is because $g'_i(L_i)$ is positive by assumption. Thus, the term $R^M - g'_i(L_i)$ may in general

be positive or negative. This indeterminacy results because there are two opposing effects at work. When in-house production increases, direct material usage goes down. This input usage is shifted into usage of the other two inputs and this creates the two opposing effects. If material cost is shifted to direct labor cost, there is the standard allocation base effect. Therefore, *more* cost is allocated to contract *i*. If direct material is shifted to overhead, *less* cost is allocated to contract *i*. Thus, the first effect causes R^M dollars to be shifted toward contract *i*; the second effect causes $g'_i(L_i)$ dollars to be shifted away from contract *i*. The net result is that $[R^M - g'_i(L_i)]$ dollars are shifted toward contract *i*.

Therefore, in general, the nature of the distortion in the level of subcontracting is indeterminate. If

$$R^M - g'_i(L_i) > 0, \quad (3.28)$$

then the same qualitative result found in all previous subsections will hold. Namely, the firm will have the incentive to use too much (too little) direct labor on contracts that are of above-average (below-average) cost-sensitivity. This translates into the firm having the incentive to do too little (too much) subcontracting on contracts that are of above-average (below-average) cost-sensitivity. However, if

$$R^M - g'_i(L_i) < 0, \quad (3.29)$$

then exactly the opposite qualitative result will hold.

The ability to develop a precise prediction from this model, therefore, depends upon whether it can be argued that the term

$$R^M - g'_i(L_i) \quad (3.30)$$

will, in general, be either always positive or always negative. Fortunately, such a conclusion appears possible. In particular, it will be argued below that Eq. (3.30) should, in general, be positive for typical defense firms. Therefore, the same qualitative predictions regarding the nature of the direct labor choice found in previous subsections seem likely to hold.

The reason that Eq. (3.30) is likely to be positive will now be explained. View the overhead rate as a function of direct labor.

$$R^M = \frac{\sum_{j=1}^n g_j(L_j) + J}{\sum_{j=1}^n L_j} \quad (3.31)$$

Then, the derivative of the overhead rate with respect to L_i is given by

$$\frac{\partial R^M}{\partial L_i} = \frac{g'_i(L_i) - R^M}{\sum_{j=1}^n L_j} \quad (3.32)$$

In particular, then, Eq. (3.30) is positive if and only if $\partial R^M / \partial L_i$ is negative.¹

It is a well-accepted stylized fact in defense procurement circles that $\partial R^M / \partial L_i$ is negative. That is, if the firm accepts more business and thus employs more direct labor, its overhead rate will be lower. Defense analysts typically speak of L_i as a measure of the "business base" and describe the result as being that "the overhead rate is a declining function of the business base."² The reason typically given for this is the existence of "fixed costs" in the overhead pool, which should be thought of as representing economies of scale or scope. The result is that although direct labor goes up proportionately with the "amount" of business, a variety of overhead costs do not. This implies that overhead rates decline as direct labor usage increases. Therefore, it seems likely that the typical defense firm is in a situation where its overall overhead rate would decline if it brought more production in-house.

¹An intuitive explanation for this precise equivalence between the sign of $\partial R^M / \partial L_i$ and the nature of the distortion in the firm's labor choice can be seen by considering the case where subcontracting has no effect on the overhead rate. That is, decreased subcontracting on product i raises L_i but also raises Z_i so that R^M is unchanged. The important point to note is that this means that the amount of overhead assigned to all other products stays absolutely constant. (Overhead assigned to some other product j depends on product j 's direct labor use and the overhead rate. Neither of these change.) Therefore subcontracting has no overhead reallocation effect. Therefore the basic intuition of this report yields the desired result. Since subcontracting has no effect on overhead allocation, the firm chooses the cost-minimizing level of inputs.

²See DoD (1986) chapter 6, for a statement to this effect in the DoD's standard procurement text. See McCullough and Balut (1990) for an empirical analysis.

This part will conclude with a simple example illustrating this "fixed-costs" view of overhead. Suppose that each g_i function is given by

$$g_i(L_i) = a + bL_i . \quad (3.33)$$

Thus, a is the fixed component of product i 's overhead costs. Total overhead is then given by

$$V = J + na + (b) \left(\sum_{j=1}^n L_j \right) . \quad (3.34)$$

The total fixed component of overhead equals the joint cost plus the n individual fixed components. Denote it by F .

$$F = J + na . \quad (3.35)$$

Let θ denote the share of total overhead that is fixed.

$$\theta = \frac{F}{V} . \quad (3.36)$$

It is straightforward to show that

$$R^M - g'_i(L_i) = \theta R^M . \quad (3.37)$$

Substitution of Eq. (3.37) into Eq. (3.27) yields

$$\frac{\partial \pi}{\partial L_i} = \theta R^M [\phi_i(C_i) - A] . \quad (3.38)$$

A comparison of Eqs. (3.38) and (3.19) reveals that the marginal effect on profit for the subcontracting case equals θ times the effect for the labor-material substitution case. This is intuitively reasonable. Increased labor use resulting from increased in-house production is essentially a labor-material substitution if overhead costs are fixed.

Finally, it should be noted that the extent to which overhead is fixed will depend greatly on the time horizon being considered. In the short run, many facilities capital costs and indirect labor costs asso-

ciated with the facilities capital will be relatively fixed, whereas in the long run, these costs will be variable. Thus, in the short run θ may be relatively high; in the long run, it may be fairly low, perhaps even zero.

The intuitive³ implication of this is that firms may design the nature of their facilities to allow for the long-run first-best level of subcontracting given the expected or average level of business. However, fluctuations of business away from the expected or average level will cause the firm to deviate from the short-run first-best response in the fashion predicted above. Namely, there will be too much in-house production of cost-sensitive products and too much subcontracting of cost-insensitive products.

In particular, then, overhead allocation may cause large distortions in the way firms respond to temporary rises or falls in their business level or in the way firms respond in the short run to permanent changes in their business level. However, it may cause very little distortion in their long-run response to relatively permanent changes in their business level. Since the defense business is typically characterized as one involving both expected and unexpected fluctuations in business, the question of whether or not there are large short-run incentive problems is probably an important issue.

³Formal demonstration of this type of result is beyond the scope of this report because it would require formally modeling uncertainty and multiple production periods where some inputs are fixed.

4. FORMAL ANALYSIS OF EQUILIBRIUM

INTRODUCTION

The previous section explained the nature of the firm's incentives to distort direct labor use by examining the marginal effect of direct labor on profit for a single contract. However, technically speaking, it did not actually demonstrate that these distortions would occur in that it did not calculate equilibrium or optimal choices for the firm. This section will formally calculate equilibrium input choices for the firm and will show that the expected distortions (based upon the analysis of Sec. 3) occur.

The analysis of this section does not contribute a great deal of extra economic insight over that contributed by Sec. 3. Showing that the marginal effects identified in Sec. 3 produce the expected equilibrium distortions is a relatively straightforward technical exercise. The fact that this part of the analysis contributes little extra economic insight is the reason for presenting it in its own section. Readers less interested in technical aspects of the analysis may choose to move directly to Sec. 5.

When the results of this section simply illustrate the intuitions developed in Sec. 3, the intuitions will not be repeated here. Thus, this section will be somewhat terse and technical. However, some minor new results are obtained in the equilibrium analysis and these will be explained more fully.

THE GENERAL PROBLEM

The general problem of the firm is to choose inputs to maximize its profits subject to the constraints on its input choice reflecting technological possibilities. Recall that profits are given in Eq. (3.1) by $\Gamma(L, M, Z, J)$. Thus, the firm's problem is

$$\text{maximize } \Gamma(L, M, Z, J) \quad (4.1)$$

$$\text{subject to } (L, M, Z, J) \in P, \quad (4.2)$$

where P denotes the feasible set of inputs. The different cases considered below will correspond to different definitions of P .

To avoid discussion of trivial cases where the firm is indifferent between everything, it will be assumed that at least one product's revenues are not totally cost-sensitive. That is, for some product i

$$\phi_i'(C_i) < 1 \quad (4.3)$$

for all $C_i \geq 0$.¹

PURE WASTE

Let L^F, M^F, Z^F, J^F denote the cost-minimizing vector of inputs. In the pure-waste case, the firm can choose to increase input usage above this level if it wants. Formally

$$P = \{(L, M, Z, J) : (L, M, Z, J) \geq (L^F, M^F, Z^F, J^F)\} . \quad (4.4)$$

Proposition 1 showed that Γ is nonincreasing in M , Z , and J . Therefore, there is no reason to expect the firm to incur waste in any variable but L . (The firm can always do at least as well by not incurring waste in these other variables.) Therefore, it will be assumed that the firm chooses efficient levels for all inputs except possibly for L . Let $\Gamma(L)$ denote the firm's objective function in this reduced problem.

$$\Gamma(L) = \Gamma(L, M^F, Z^F, J^F) . \quad (4.5)$$

The firm's problem is as follows.

$$\text{Maximize } \Gamma(L) \quad (4.6)$$

¹Technically, this assumption plays the following role in the various proofs. In most cases the first-order conditions will be satisfied if $\phi_i'(C_i) = 1$ for every i . In such a case, the firm is indifferent between all cost allocations and, in general, anything could be true. Assumption (4.3) rules out this possibility. Then, the first-order conditions generally imply a great deal of structure for the resulting equilibrium.

$$\text{subject to } L_i \geq L_i^F \quad (4.7)$$

for every i .

It will be assumed that Eqs. (4.6)–(4.7) have a unique solution characterized by their first-order conditions. The solution is calculated in Appendix B and only the interesting characteristics of the solution will be reported here. (All proofs are in Appendix B.) The characteristics will be reported as a series of propositions. Let asterisks denote the values of the variables in the solution—i.e., L_i^* is the optimal labor choice for product i , C_i^* is the level of cost resulting in the optimal solution, etc. Let W denote the subset of products for which waste occurs and let N denote the subset of products for which no waste occurs. Formally,

$$L_i^* > L_i^F \text{ for } i \in W \quad (4.8)$$

$$L_i^* = L_i^F \text{ for } i \in N. \quad (4.9)$$

Proposition 3 now presents the basic characterization. Namely, products whose revenues are more cost-sensitive will be the ones exhibiting waste.

Proposition 3:

Choose $i, j \in W$, and $k \in N$. Then

$$\phi_i'(C_i^*) = \phi_j'(C_j^*) \geq \phi_k'(C_k^*). \quad (4.10)$$

Proposition 3 also states that all contracts in W will exhibit the same cost-sensitivity. The reason for this is clear. If one contract in W was more cost-sensitive than another, then the firm could increase profits by increasing waste on the former and reducing it on the latter.

Proposition 4 states that waste is never incurred on *all* of the products.

Proposition 4:

N is non-empty.

The intuition for this is very clear. The purpose of incurring waste is to shift overhead. If waste is being incurred on all products then the same shifting could be accomplished by reducing all waste levels until the waste level for one product was zero. Waste is reimbursed only partially. Therefore, if the same overhead allocation could be produced with lower waste levels, then the firm's profits would be greater.

Proposition 5 makes a weaker statement about the non-emptiness of the set W . In general, it may be that no waste is incurred. However, if at least one product is completely cost-sensitive at the cost levels existing under no waste then the firm will always find it optimal to incur some waste on that product. In particular, then, W will not be empty.

Proposition 5:

Suppose that

$$\phi_i(C_i^F) = 1 \quad (4.11)$$

for some product i . Then $i \in W$.

INPUT SUBSTITUTION

In Sec. 3 input substitution between labor and material and between labor and capital were considered as two separate problems. This was analytically useful because the separate considerations involved in each type of substitution could be clearly understood. However, in general the firm will simultaneously consider substitutions between all three inputs. Therefore, this section will demonstrate that the expected distortions in direct labor occur in a more general model that potentially allows substitutions between all three variables.²

Assume that the joint inputs remain fixed at some level J^* . For each product the firm can choose any vector of product-specific inputs satisfying

²On a technical level this generalization is relatively trivial. It will be assumed that Z_i and M_i are strong substitutes for L_i in the sense that the cost-minimizing choices of Z_i and M_i both go down when L_i goes up. Under this assumption, it is in fact sufficient to demonstrate the distortions in the two smaller problems. It is then immediate that the distortions also occur in the general problem. This will be explained in full detail below.

$$L_i = f^i(M_i, Z_i) \quad (4.12)$$

for some function f^i . Thus the feasible set of inputs is

$$P = \{(L, M, Z, J): J = J^* \text{ and } L_i = f^i(M_i, Z_i) \text{ for every } i\}. \quad (4.13)$$

Three definitions of various types of optimality will be useful before describing the properties of f^i . For any input choices the total product-specific cost is given by

$$L_i + M_i + Z_i. \quad (4.14)$$

Substitution of Eq. (4.12) into Eq. (4.14) yields

$$f^i(M_i, Z_i) + M_i + Z_i. \quad (4.15)$$

An input vector is first-best if it minimizes this cost.

Definition:

An input vector $(\hat{L}_i, \hat{M}_i, \hat{Z}_i)$ is first-best if it minimizes Eq. (4.15) and satisfies Eq. (4.12).

An ordered pair of inputs will be called second-best given the third input if it minimizes cost given the third input.

Definition:

The ordered pair (\hat{L}_i, \hat{M}_i) is second-best given \hat{Z}_i if $(\hat{L}_i, \hat{M}_i, \hat{Z}_i)$ minimizes Eq. (4.14) subject to Eq. (4.12) and subject to $Z_i = \hat{Z}_i$. All other notions of second-best for other ordered pairs of inputs are defined analogously.

The properties that f^i is assumed to satisfy will now be formally listed. A discussion will follow.

Properties of f^i :

- (a) The function f^i is defined over the nonnegative reals and maps into the nonnegative reals. It is twice continuously differentiable.
- (b) There is a unique first-best input vector. Denote it by (L_i^F, M_i^F, Z_i^F) .

- (c) There is a unique second-best (L_i, M_i) given Z_i . Let $L_i^s(Z_i)$ and $M_i^s(Z_i)$ denote the two functions determining these values.
- (d) There is a unique second-best (L_i, Z_i) given M_i . Let $L_i^s(M_i)$ and $Z_i^s(M_i)$ denote the two functions determining these values.

$$(e) \quad f_M^i < 0 \quad (4.16)$$

$$f_z^i < 0 \quad (4.17)$$

$$(f) \quad f_{MM}^i > 0 \quad (4.18)$$

$$f_{zz}^i > 0 \quad (4.19)$$

$$f_{MM}^i f_{zz}^i - (f_{Mz}^i)^2 > 0 \quad (4.20)$$

$$(g) \quad f_{Mz}^i < 0 \quad (4.21)$$

$$f_M f_{MM} - f_z f_{Mz} > 0 \quad (4.22)$$

$$f_z f_{zz} - f_M f_{Mz} > 0 \quad (4.23)$$

Assumptions (a)–(d) simply require f^i to be a smooth function with solutions to the various cost-minimization problems of interest. Assumption (e) states that Z_i and M_i are substitutes for L_i and assumption (f) simply requires f^i to be convex. Given the above assumptions, assumption (g) is simply equivalent to the assumption that all inputs are strong substitutes in the sense that the second-best inputs given the third input are both decreasing in the third input. That is, if the third input goes up then it is optimal to reduce use of both of the other inputs. This is straightforward to show so it will not be formally demonstrated. The only role that assumption (g) plays is to mildly strengthen the nature of the conclusions at one step in the analysis. This step will be identified below.

The firm's optimization problem can now be formalized as follows. Let $\Gamma(L, M, Z)$ denote the firm's profits when J is held at its fixed value—i.e.,

$$\Gamma(L, M, Z) = \Gamma(L, M, Z, J^*) . \quad (4.24)$$

Then the firm's problem can be written as

$$\text{Maximize } \Gamma(L, M, Z) \quad (4.25)$$

$$\text{subject to } L_i = f^i(M_i, Z_i) \quad (4.26)$$

for every i .

It will be assumed that a unique interior solution exists to Eqs. (4.25)–(4.26) characterized by the first-order conditions. The solution and all proofs are in Appendix C and only the interesting characteristics of the solution will be reported here. Let asterisks denote the values of variables in the solution—i.e., L_i^*, Z_i^* is the solution for product i , C_i^* is the resulting cost for product i , A^* is the resulting weighted average cost-sensitivity, etc.

Proposition 6 now states the major result of this subsection. In equilibrium, the firm uses too much (too little) direct labor on products that are of above-average (below-average) cost-sensitivity.

Proposition 6:

$$\begin{array}{ccc} & > & \\ L_i^* = L_i^F & \Leftrightarrow \phi_i'(C_i^*) = A^* & \\ & < & \end{array} \quad (4.27)$$

This is, of course, precisely the expected result based on the analysis of Sec. 3 so no further explanation will be offered. It should be noted that the expected distortions also occur with respect to the second-best criteria. This is stated as Proposition 7.³

³In fact the method of proof is to first prove Proposition 7. Then Proposition 6 follows immediately because of assumption (g) that all the inputs are strong substitutes.

Proposition 7:

$$\begin{matrix} > \\ L_i^* = L_i^s(Z_i^*) \Leftrightarrow \phi_i'(C_i^*) = A^* \\ < \end{matrix} \quad (4.28)$$

$$\begin{matrix} > \\ L_i^* = L_i^s(M_i^*) \Leftrightarrow \phi_i'(C_i^*) = A^* \\ < \end{matrix} \quad (4.29)$$

One final comment regarding the issue of pure waste will be made before concluding this part. The formal model considered in this part did not allow the firm to engage in pure waste. However, it is straightforward to allow the firm this additional option and to show that the firm will never have the incentive to engage in any type of pure waste, including direct labor waste. The intuition for and interpretation of this result were discussed in Sec. 3.

SUBCONTRACTING

As in the above subsection, assume that J is fixed at some level J^* . Then the feasible set is defined by

$$P = \{(L, M, Z, J): Z_i = g_i(L_i); M_i = h_i(L_i); J = J^*\} . \quad (4.30)$$

Assume that a unique level of first-best inputs exists for every i . Denote each of these by L_i^F, M_i^F, Z_i^F . They satisfy the following program:

$$\begin{aligned} &\text{Minimize } L_i + g_i(L_i) + h_i(L_i) \\ &L_i, M_i, Z_i \end{aligned} \quad (4.31)$$

$$\text{subject to } M_i = h_i(L_i) \quad (4.32)$$

$$Z_i = g_i(L_i) . \quad (4.33)$$

Furthermore, assume that the objective function (4.31) is single-peaked.

Let $\Gamma(L, M, Z)$ denote the firm's profits when J is held at its fixed value as defined by Eq. (4.24). Then, the firm's problem can be written as follows.

$$\text{Maximize } \Gamma(L, M, Z) \quad (4.34)$$

$$\text{subject to } M_i = h_i(L_i) \quad (4.35)$$

$$Z_i = g_i(L_i) . \quad (4.36)$$

As usual, it will be assumed that a unique interior solution to Eqs. (4.34)–(4.36) exists which is characterized by the first-order conditions. The formal analysis and all proofs are in Appendix D and only the major qualitative results will be reported here. Let variables with a superscript of "*" denote the values that the variables assume under the solution. Proposition 8 now states the major result.

Proposition 8:

(i) Suppose that $[R^{M*} - g'_i(L_i^*)] > 0$. Then

$$\begin{array}{ccc} & > & \\ L_i^* = L_i^F & \Leftrightarrow & \phi'_i(C_i^*) = A^* \\ & < & \end{array} \quad (4.37)$$

(ii) Suppose that $[R^{M*} - g'_i(L_i^*)] < 0$. Then

$$\begin{array}{ccc} & > & \\ L_i^* = L_i^F & \Leftrightarrow & \phi'_i(C_i^*) = A^* \\ & < & \end{array} \quad (4.38)$$

(iii) Suppose that $[R^{M*} - g'_i(L_i^*)] = 0$. Then

$$L_i^* = L_i^F \quad (4.39)$$

or

$$\phi_i'(C_i^*) = 1 . \quad (4.40)$$

These, of course, are precisely the expected results based on Sec. 3. In particular, recall that Sec. 3 argued that case (i) is the most likely to actually apply to real cases of interest. In this case, the qualitative nature of the direct labor distortions is exactly the same as for the input substitution case.

5. EMPIRICAL ESTIMATES OF THE MAGNITUDE OF THE INCENTIVE EFFECTS

INTRODUCTION

This section will assess the empirical significance of the incentive effects described in this report. The method for doing so will be as follows. Section 3 developed formulas that determine the marginal impact of direct labor usage on profit as a function of various parameters, including the overhead rate and cost-sensitivity of the firm's contracts. This section will substitute in plausible values for these parameters and thus will estimate plausible values for the marginal impact of direct labor usage on profit.

It will be seen that the estimated effects are quite significant. For example, it is estimated that a dollar of direct labor waste on a cost-sensitive defense contract might increase a typical firm's revenue by between \$1.20 and \$1.44. That is, there is a CPPC effect of 20-44 percent.

One remark regarding interpretation should be noted about these estimates. In the equilibrium calculated in Sec. 4, the firm will have taken advantage of all such opportunities to increase its profits and the marginal effect of direct labor on profit will be zero. (This is the first-order condition.) Thus, in the context of the model of Sec. 4, one should interpret the calculations of this section as providing plausible estimates of the incentives a firm might face to engage in input distortions or waste before actually doing so. Also, it should be noted that the model of Sec. 4 did not allow auditing to play any role at all in restraining firms' waste. In reality, firms may often perceive gains to engaging in direct labor distortions but auditing prevents them from realizing these gains. Thus, one could also interpret the calculations of this section as providing estimates of the actual equilibrium incentives in a more complicated model where auditing partially restrains defense firms' behavior.

To make best use of the actual data, it will be useful to complicate the formal model of Sec. 3 in one respect. The one major exception to the general rule that "most defense firms allocate most of their overhead based on direct labor" concerns an overhead element usually labeled general and administrative (G&A). This basically consists of the cost of central management functions. It is typically allocated over a base

that includes direct labor as one of its elements but also includes other elements. Although it is small enough that one could simply ignore the entire G&A pool and produce estimates that are relatively close to correct, it is fairly straightforward to alter the formulas of Sec. 3 to explicitly include the effects of the G&A pool.

None of the basic intuitions of Sec. 3 are altered. One factor determining the size of the firm's incentive to shift overhead is the number of dollars of overhead that a dollar of direct labor attracts. Formally modeling the more complicated way that the G&A pool is allocated simply produces a more refined estimate of the number of dollars of overhead that a dollar of direct labor attracts. In particular, direct labor is not as effective at shifting dollars in the G&A pool as other overhead dollars.

The consideration of the more complex manner in which G&A is allocated simply produces a more complex set of formulas that yield few new qualitative results. This feature was not included in the previous sections because their goal was to clearly and simply demonstrate the basic ideas of this report. However, for purposes of actual estimation it is more important to include the complication. In particular, this produces a more conservative estimate than would be had by simply assuming that G&A is entirely allocated according to direct labor. Since the conclusion of this section is that the incentive effects are large, it is important to remove such potential upward biases from the estimation procedure to the extent possible.

The subsection below will formally describe the two-pool overhead allocation system that it will be assumed the firm uses. Then the analogous formulas to those in Sec. 3 will be derived. Plausible values for the various parameters in the formulas will be developed. Finally, the empirical estimates of the marginal impact of direct labor on profit for the various cases of interest will be presented.

DESCRIPTION OF THE GENERALIZED MODEL

The generalized cost-allocation model used in this subsection will be exactly the same as that described in Sec. 3 except for one additional feature. Direct labor and material are still denoted by L_i and M_i . The overhead described there still exists, still can be broken into product-specific and joint components, and is still allocated according to direct labor. However, it will now be called manufacturing and engineering (M&E) overhead instead of simply overhead. Similarly, the overhead rate, R^M , will now be called the M&E overhead rate. Thus, Eqs. (2.6)–(2.9) are still true. The one difference in the generalized model is that

it will be assumed that an additional overhead pool exists that will be called the G&A pool. Let G denote its dollar value. It will be assumed that all of the costs in G are joint.

The G&A pool's major distinguishing feature is that it is allocated in a somewhat more complicated fashion than is the M&E pool. Define the total cost input for contract i , denoted by T_i , to be direct labor and material plus the allocated share of the M&E pool.

$$T_i = M_i + L_i(1 + R^M) . \quad (5.1)$$

Then the G&A pool is allocated according to total cost input. Let G_i denote the amount of G&A overhead allocated to contract i . It is given by

$$G_i = \frac{T_i}{\sum_{k=1}^n T_k} G . \quad (5.2)$$

Let R^G denote the G&A overhead rate given by

$$R^G = \frac{G}{\sum_{k=1}^n T_k} . \quad (5.3)$$

Then, Eq. (5.2) can be rewritten as

$$G_i = T_i R^G . \quad (5.4)$$

The total cost of contract i , denoted by C_i , is given by

$$C_i = L_i + M_i + V_i + G_i , \quad (5.5)$$

which can be rewritten as

$$C_i = (1 + R^G) \{ L_i(1 + R^M) + M_i \} . \quad (5.6)$$

Before proceeding to the calculation of formulas for the marginal effect on profit, one further simplification will be introduced. In the

analysis of the single-pool cost-allocation system in Sec. 3, the average cost-sensitivity given by

$$A = \sum_{i=1}^n \left(\frac{L^i}{\sum_{k=1}^n L_k} \right) \phi'_i(C_i) . \quad (5.7)$$

played a role. This is because the weights corresponded to overhead shares. In the two-pool analysis of this section, the parameter A will continue to play a role because M&E overhead is still allocated according to these shares. However, G&A is allocated according to different shares. In particular, contract i will receive the share

$$\frac{T_i}{\sum_{k=1}^n T_k} \quad (5.8)$$

of G&A overhead. Therefore, it should not be surprising that the weighted average cost-sensitivity calculated according to these weights will also play a role. Call this value A^T .

$$A^T = \sum_{i=1}^n \left(\frac{T^i}{\sum_{k=1}^n T_k} \right) \phi'_i(C_i) . \quad (5.9)$$

In general, there is no reason to believe that A and A^T will be the same. Generally speaking, this would only be true if the ratio

$$L_i / M_i \quad (5.10)$$

stayed constant across contracts. However, for purposes of empirical implementation, no data are available on how the ratio in Eq. (5.10) varies between contracts and how this variation is correlated with cost-sensitivity. Therefore, it will be assumed that A^T and A are equal. Let A denote this common value.

ANALYSIS OF THE GENERALIZED MODEL

This section will basically repeat the analysis of Sec. 3. It will be seen that the existence of the extra overhead pool alters the formulas in an extremely intuitive fashion and that almost all of the intuition and analysis of Sec. 3 still applies in a slightly altered fashion.

Proposition 9 is the analogue to Proposition 1 and presents the derivatives of profit with respect to the input variables. Since the proofs simply involve straightforward differentiation, they will not be presented.

Proposition 9:

$$\frac{\partial \Gamma}{\partial M_i} = (\phi'_i(C_i) - 1) + R^G(\phi'_i(C_i) - A) \quad (5.11)$$

$$\frac{\partial \Gamma}{\partial Z_i} = A - 1 \quad (5.12)$$

$$\frac{\partial \Gamma}{\partial M_j} = A - 1 \quad (5.13)$$

$$\frac{\partial \Gamma}{\partial G} = A - 1 \quad (5.14)$$

$$\frac{\partial \Gamma}{\partial L_i} = [R^M + R^G(1 + R^M)] [\phi'_i(C_i) - A] + [\phi'_i(C_i) - 1] . \quad (5.15)$$

Each formula in Proposition 9 will now be compared with the analogous formula in Proposition 1. First consider Eq. (5.11). Now, direct material attracts R^G dollars of overhead. Thus, the second term is added to Eq. (5.11) to reflect the effect on profit of shifting R^G dollars of overhead. The next three formulas show that the marginal effect of increasing any type of overhead still equals $A - 1$, just as for Proposition 1. Finally, consider Eq. (5.15). Let D denote the following term in Eq. (5.15).

$$D = R^M + R^G(1 + R^M) . \quad (5.16)$$

The difference between Eqs. (3.6) and (5.15) is that the term R^M in Eq. (3.6) is replaced by the term D in Eq. (5.15). The reason for this is straightforward. In the single-pool case, \$1 of direct labor attracted R^M dollars of overhead. This is why R^M was the appropriate value to use in Eq. (3.6). However, in the multiple-pool case of this subsection, \$1 of direct labor attracts D dollars of overhead. It attracts

$$R^M \quad (5.17)$$

dollars from the M&E pool. However, this creates $(1 + R^M)$ dollars of total cost input, which in turn attracts

$$R^G(1 + R^M) \quad (5.18)$$

dollars from the G&A pool. The sum of Eqs. (5.17) and (5.18) is D .

Thus, there are only two differences in the multiple-pool case. First, direct material now attracts R^G dollars of overhead instead of 0 dollars of overhead. Second, direct labor attracts D dollars of overhead instead of R^M dollars of overhead. All the formulas for the multiple-pool case are simply the natural analogues to the formulas for the single-pool case where adjustments are made for these two differences.

Now consider input substitution. Just as in Sec. 3, view L_i as the choice variable for the firm with the required values of Z_i and M_i given by Eqs. (3.13) and (3.14). Let $\pi(L)$ denote the firm's profits. Proposition 10 presents the general formula for the marginal effect of direct labor on profit. This is the analogue to Proposition 2. The proof is similar to that for Proposition 2 and will not be supplied.

Proposition 10:

$$\begin{aligned} \frac{\partial \pi}{\partial L_i} = & [1 + R^G] [R^M - g'_i(L_i)] [\phi'_i(C_i) - A] \\ & + [1 + h'_i(L_i) + g'_i(L_i)] [\phi'_i(C_i) - 1] . \end{aligned} \quad (5.19)$$

These general formulas will now be applied to all the cases considered in Sec. 3. The assumptions defining each case will not be repeated here. The reader should refer to Sec. 3 as necessary.

Pure Waste

Formula (5.15) gives the marginal effect of direct labor waste on profit. As just stated, the only difference in the multiple-pool case is that R^M is replaced by D , because now \$1 of direct labor attracts D dollars of overhead.

Labor-Material Substitution

The analogue to Eq. (3.19) is now given by

$$\frac{\partial \pi}{\partial L_i} = (D - R^G) [\phi'_i(C_i) - A] . \quad (5.20)$$

The difference between these two formulas is that the term R^M in Eq. (3.19) has been replaced by the term $D - R^G$ in Eq. (5.20). The reason for this is straightforward. In the single-pool case, substitution of a dollar of direct labor for a dollar of direct material attracted R^M dollars of overhead to contract i . This is why R^M is the appropriate value to use in Eq. (3.19). However, in the multiple-pool case the situation is slightly more complex. The increased dollar of direct labor attracts D dollars of overhead but the reduced dollar of direct material takes away R^G dollars of overhead. The net amount of overhead attracted is $D - R^G$ dollars.

Labor-Overhead Substitution

The analogous formula to Eq. (3.22) is

$$\frac{\partial \pi}{\partial L_i} = (1 + D) [\phi'_i(C_i) - A] . \quad (5.21)$$

Thus, the only difference between Eqs. (3.22) and (5.21) is that the term $1 + R^M$ is replaced by the term $1 + D$. The reason for this is as explained above—i.e., \$1 of direct labor now attracts D dollars of overhead.

Subcontracting

The analogous formula to Eq. (3.27) is

$$\frac{\partial \pi}{\partial L_i} = (1 + R^G) [R^M - g'_i(L_i)] [\phi'_i(C_i) - A] . \quad (5.22)$$

The only difference between Eqs. (3.27) and (5.22) is that Eq. (3.27) is multiplied by $(1 + R^G)$ to yield Eq. (5.22). The reason for this is as follows. By assumption, we are considering input changes that have a net effect of zero—i.e., the sum of the changes equals zero. Therefore, both total cost input (total cost minus G&A) and G&A remain constant. Therefore R^G also remains constant. This means that the marginal effect on profit can be calculated in two steps.

Step #1: Ignore the G&A pool by assuming $R^G = 0$. Calculate the change in profit using the formula from Sec. 3.

Step #2: Multiply by $(1 + R^G)$ to reflect the change in G&A allocation.

This yields Eq. (5.22).

Therefore, all of the analysis of Eq. (3.27) still applies to this case. The only difference is that the effect is multiplied by $(1 + R^G)$, which has no qualitative effect. In particular, all of the discussion surrounding the term

$$R^M - g'_i(L_i) \quad (5.23)$$

still applies. The formula for the example where M&E overhead has a fixed and linear component is now¹

$$\frac{\partial \pi}{\partial L_i} = \theta(D - R^G) [(\phi'_i(C_i) - A)] , \quad (5.24)$$

where, recall, θ is the proportion of fixed M&E overhead. This is the formula that will be used for estimation purposes. Note that the same relationship between the effects for the subcontracting and labor-material substitution cases still is true. The former equals θ times the latter. The same intuition still explains this. Increased labor use resulting from increased in-house production is essentially a labor-material substitution if overhead is fixed.

OVERVIEW OF THE EMPIRICAL ESTIMATION

Table 5.1 displays the formulas determining the marginal impact of direct labor on profit for all the cases of interest.

¹Substitution of Eqs. (3.37) and (5.16) into Eq. (5.22) yields Eq. (5.24).

Table 5.1
The Marginal Impact of Direct Labor on Profit

Case	Formula
Pure waste	$D[\phi'_i(C_i) - A] + [\phi'_i(C_i) - 1]$
Labor-material substitution	$(D - R^G)[\phi'_i(C_i) - A]$
Labor-overhead substitution	$(D + 1)[\phi'_i(C_i) - A]$
Subcontracting	$\theta(D - R^G)[\phi'_i(C_i) - A]$

The first term of all four formulas is the same. It gives the profit from overhead shifting and is of the form

$$x[\phi'_i(C_i) - A], \quad (5.25)$$

where x is the number of dollars of overhead shifted by \$1 of direct labor (and varies from case to case) and $[\phi'_i(C_i) - A]$ is the profit per dollar of overhead shifted (and is the same for every case). This is the only term for the three input substitution cases, since by assumption an increase in direct labor is coupled with an equal decrease in other inputs. For the pure-waste case one must also consider the impact on profit from the increase in direct cost resulting from the expenditure on direct labor. This is given by the second term of that formula.

Therefore, to estimate plausible values for the size of the marginal impact of direct labor on profit, one must determine plausible values for three groups of parameters. The first group is overhead rates, R^M and R^G , and the second group is the single parameter θ . These determine the value of x . The third group is the cost-sensitivity parameters $\phi'_i(C_i)$ and A .

Each group will now be discussed in turn.

OVERHEAD RATES

This subsection will develop plausible estimates to use for the overhead rates, R^M and R^G , by determining the average values of these two rates for four major aerospace contractors in 1987. The four contractors are General Dynamics Forth Worth Division, Grumman Aerospace Company, McDonnell Aircraft Company, and Northrop Aircraft Company. The data for these calculations are from a study of the cost-accounting systems of these four firms for the years 1974-

1987 conducted by the Institute for Defense Analysis (McCullough and Balut, 1990). Readers wanting more data and a fuller explanation should consult this paper directly.²

First, it should be noted that the overhead allocation process for these four firms is essentially as described by the generalized model in the subsection above. All four firms allocate G&A according to total cost input. Almost all overhead other than G&A is allocated according to direct labor. Many of the firms divide M&E overhead into a number of smaller pools and allocate each pool according to a particular type of direct labor. For example, many firms have separate manufacturing and engineering overhead pools that are allocated, respectively, according to manufacturing direct labor and engineering direct labor. However, this subdivision does not cause any essential changes and thus will be ignored. In reality, the overhead rates between pools will vary somewhat and the incentive to distort each type of direct labor will vary accordingly. This section can be viewed as calculating the average incentive.

Table 5.2 presents the breakdown of 1987 costs into various cost pools and Table 5.3 presents the calculations of R^M , R^G , and D .

A number of adjustments had to be made to the data from McCullough and Balut (1990) to produce Table 5.2. A complete description of these adjustments is contained in Appendix E. The four most important adjustments will be briefly noted here. First, allowable independent research and development and bid and proposal

Table 5.2
Breakdown of Costs

Cost Type	Cost (\$ thousands)	% of Total
Direct labor	2,333,994	20.1
Direct material	6,025,409	51.9
Overhead	3,259,095	28.0
G&A	940,243	8.1
M&E	2,318,852	19.9
Total	11,618,498	100.0

²I am particularly indebted to James McCullough for answering many questions regarding the interpretation of their data.

Table 5.3
Value of Overhead Rates

Rate	Value
R ^M	0.99
R ^G	0.09
D	1.17

(IR&D/B&P) expenditures are included in the G&A pool.³ This is because IR&D/B&P is required to be allocated in the same manner as G&A. Also note that only *allowable* expenditures (i.e., expenditures that the DoD recognizes for pricing purposes) were included, since only these affect defense products' prices.

Second, there is a small amount of overhead called material handling overhead, which is allocated according to some measure of direct material use. This has simply been included as part of direct material. The overhead is too small to make any difference so is ignored for expositional clarity. Also, there are a variety of direct charges, which are neither labor nor material. These are called other direct charges (ODCs). The largest of these is directly charged computer time. From the standpoint of this report they are mathematically equivalent to direct material (i.e., they are a direct charge that is not used as an allocation base) so they have been included in direct material. Finally, some readers may wonder why direct material is such a large figure. This is because it includes all directly charged subcontracted items.

Third, fringe benefits for direct labor have been included as part of direct labor. Firms normally classify fringes as part of overhead. However, there is no incentive problem created by placing fringes in the overhead pool. This is because the firm cannot spend an extra dollar on direct labor without also spending proportionately more on fringes as well. One might call these *linked costs*. Since no incentive problem is created by placing fringes in overhead, the correct procedure for estimating the magnitude of incentive effects is to remove them from the overhead pool and reclassify them as direct.

Fourth, McCullough and Balut (1990) did not include the elements of economic cost that the DoD labels as a "profit." These are primarily a return for risk bearing, working capital, and facilities' capital. Other

³For those unfamiliar with this term, IR&D/B&P expenditures are discussed further in Appendix D and in Sec. 7.

than for facilities capital this exclusion is of no great concern. This is because the profit for each contract is directly calculated and no other costs are allocated based on these charges. Thus, they can be viewed as direct charges that bear no overhead and they are therefore irrelevant to the calculations in this report. However, facilities capital profit is allocated according to direct labor use just as in the M&E pool. Therefore, from the standpoint of this report facilities capital profit is mathematically equivalent to any other M&E cost, so it has been added to the M&E pool.

These four major adjustments were made to the McCullough and Balut (1990) data. The only truly significant impact was created by the third adjustment—reclassifying fringes as direct. This lowers overhead rates and thus reduces the magnitude of the estimated incentives to distort direct labor.

To conclude, it should be noted that, although the calculations of this section rely on data from only four aerospace firms, based on extensive discussions with industry and government personnel, I believe that these four firms are in fact representative of a broad segment of the defense industry in two senses. First, their practice of allocating almost all overhead except G&A based on direct labor and allocating G&A based on total cost input is the norm. Second, the overhead rates of these four firms are very typical.

Some extra empirical evidence is available on this second point. The Logistics Management Institute (Meyers et al., 1985) has published an average cost breakdown for 5,434 (randomly selected) contracts negotiated in 1980–1982. Using these data, one can derive estimates for the overhead rates as displayed in Table 5.4. These values are very close to those estimated in Table 5.3.⁴ The derivation of these estimates is presented in Appendix F.

⁴The data from McCullough and Balut (1990) were used instead of those from Meyers et al. (1985) for two reasons. First, the McCullough and Balut data were much more detailed and contained, for example, data on IR&D/B&P expenditures and fringe benefits, which allowed precise adjustments to be made. Second, the McCullough and Balut data are actual incurred cost data. The Meyers et al. data are taken from the forms firms must fill out when they submit cost estimates before negotiations for a new contract. Thus, those data do not necessarily represent actual costs. Because of these two problems it was felt that the McCullough and Balut data were preferable even though they were based on fewer firms. Nonetheless, it is reassuring that one can derive relatively similar overhead rates using the Meyers et al. data.

Table 5.4
Estimated Overhead Rates
Using LMI Data

Rate	Value
R^M	0.87
R^G	0.14
D	1.09

FIXED OVERHEAD AS A SHARE OF TOTAL OVERHEAD

Both the DoD and defense firms routinely calculate linear regressions of a firm's total overhead expenditures on direct labor and other variables. The reason for this is that such regressions provide the basis for estimating future overhead rates and thus future costs. (One directly estimates future direct labor use and then applies the regression equation to estimate future overhead.) This technique is in fact widely used by both commercial and defense firms and is often given the label "flexible budgeting" in standard commercially oriented accounting texts.⁵ Thus, there is perhaps some reason to believe that it is reasonably accurate to assume that a linear relationship exists (in the relevant range) between direct labor and overhead as the amount of business in the firm varies.

Unfortunately most of these studies are proprietary and not publicly available. An exception is reported in McCullough and Balut (1990). They run the following regression for each of the four aerospace firms in their main study plus two additional firms—Lockheed-California and Sikorsky.⁶

$$y_t = \alpha + \beta_1 x_{1t} + \beta_2 x_{2t} \quad (5.26)$$

The notation is as follows:

- y_t = total overhead expenditures in year t
- x_{1t} = net book value of assets in year t
- x_{2t} = total direct labor expenditures in year t ⁷

⁵See, for example, Horngren and Foster (1987), chapters 6 and 7.

⁶See McCullough and Balut (1990) for details. The results reported there are actually attributed to another IDA researcher, Tom Frazier. No separate publication of these results is cited.

⁷Actually, direct labor *hours* were used. This should not have any effect.

\bar{x}_1 = the mean of x_{1t}
 \bar{x}_2 = the mean of x_{2t} .

The net book value variable is added in an attempt to distinguish between the long and short run. In particular, the authors interpret the amount of overhead that is fixed in the short run as being given by

$$F = \alpha + \beta_1 \bar{x}_1 . \quad (5.27)$$

Recall that in Sec. 3 it was argued that short-run incentives are significant because of the prevalence of both expected and unexpected fluctuations in defense firms' business levels. Therefore, this subsection will estimate the magnitude of the short-run incentive effects, i.e., the value of F given by Eq. (5.27) will be used to calculate θ .

The value of θ can now be calculated. Define ψ to be the share of total overhead that is fixed in the short run. It is given by

$$\psi = \frac{F}{\alpha + \beta_1 \bar{x}_1 + \beta_2 \bar{x}_2} , \quad (5.28)$$

where F is given by Eq. (5.27). McCullough and Balut (1990) calculate ψ for all six firms and report its average value. This is 0.58. However, this is *not* the value of θ , since θ is the share of *M&E* overhead that is fixed. It seems reasonable to conjecture that most G&A is relatively fixed in the short run. Thus, θ will be less than 0.58. To correct for this, it will be assumed that all G&A is fixed. This is conservative in that it yields the smallest value of θ . From Table 5.2 G&A is 29 percent of total overhead. Thus, θ is given by

$$\theta = \frac{0.58 - 0.29}{1 - 0.29} = 0.41 . \quad (5.29)$$

This is the value of θ that will be used for estimation purposes.

CONTRACT MIX BY COST SENSITIVITY

Development of the overhead rates to use for estimation purposes was relatively straightforward and noncontroversial, since real data exist. The estimation of θ was more problematic but was at least still based

on real data.⁸ The question of what values the cost-sensitivity parameters ought to assume is difficult because no actual data exist.

For purposes of constructing estimates, this report will assume that the firm does have some contracts that are extremely cost-sensitive and some contracts that are extremely cost-insensitive. In particular, it will be assumed that contract 1 is perfectly cost-sensitive and contract n is perfectly cost-insensitive.

$$\phi'_1(C_1) = 1 \quad (5.30)$$

$$\phi'_n(C_n) = 0 \quad (5.31)$$

The marginal effect of direct labor changes on profit will be calculated for these two contracts. This provides estimates of the two extremes of incentive effects that the firm will experience.

The assumption that these two extreme cost-sensitivities exist does not appear unreasonable. As discussed in Sec. 2, most students of military procurement would agree that prices on a wide variety of procurements are highly cost-based. For the other extreme, one can appeal to the existence of commercial products. Most major defense firms produce both commercial products and defense products in the same business segment. (Data on the average values of commercial business will be supplied below.) Even when a firm has no commercial business, it may be that the intense competition to obtain early contracts in a procurement program may mean that the price is determined quite independently of cost on these. This was also discussed more thoroughly in Sec. 2.

The remaining, and more difficult, question that must be addressed concerns the value of A, the average cost-sensitivity of all of the firm's contracts. The effect of the size of A on the estimates is determined by the fact that shifting \$1 of overhead to contract i produces a net change in profit of

$$\phi'_i(C_i) - A \quad (5.32)$$

dollars. Thus, for the cost-sensitive contract the incentive to shift overhead toward it will be larger as A grows smaller and will be at a

⁸Furthermore, it is not that important, since only the subcontracting case uses it.

maximum if A equals zero. The situation is reversed for the cost-insensitive contract.

This report will consider four different estimates of A . The first estimate will simply be

$$A = 0 . \quad (5.33)$$

This is not meant to be generally realistic or typical. It simply measures the maximum possible incentive that could exist to use too much labor on the cost-sensitive contract. This corresponds to a scenario where all contracts except contract 1 are completely cost-insensitive and contract 1 is extremely small.

The second estimate will be

$$A = 1 . \quad (5.34)$$

This, in a similar spirit to that above, measures the maximum possible incentive that could exist to use too little labor on contract n . It corresponds to a situation where all contracts except contract n are completely cost-sensitive and contract n is extremely small.

The third estimate will be constructed by assuming that all of the firm's government contracts are completely cost-sensitive and all of the firm's commercial contracts are completely cost-insensitive. Then, the industry average for the proportion of government business will be used to construct the value of A . Let D denote the fraction of direct labor used by the firm's DoD contracts. Then A is given by

$$A = D . \quad (5.35)$$

In its last major statistical analysis of all major defense contractors, the DoD (1985) found that, on average, major defense contractors' business was 82.8 percent government and 17.2 percent commercial.⁹ This yields an estimate for A of

⁹These figures are from *DFAIR* (DoD, 1985) for the year 1983, which was the most recent year in the study. It reports that on average 17.2 percent of operating costs were allocated to commercial contracts. Since the allocation is based almost entirely on direct labor, this is a reasonable approximation to use for the fraction of direct labor assigned to commercial contracts. Note that if firm A performed a subcontract for firm B as part of a government contract that firm B was performing, then the subcontract would be labeled as noncommercial for the purposes of classifying firm A's business. Thus, the 17.2 percent is truly commercial work. Finally, note that the *DFAIR* analysis was on the profit center level. That is, it considered individual segments of a

$$A = 0.828 . \quad (5.36)$$

There is a sense in which this third estimate is biased upward. Although it is reasonable to assume that all of a firm's commercial business is priced independently of accounting costs, it is probably not as reasonable to assume that all of its defense business is perfectly cost-sensitive. At least a muted level of competitive forces will be at play on some of the firm's defense contracts. To the extent that some of a typical firm's defense business is less than perfectly cost-sensitive, this will tend to lower the value of A.

To attempt to account for this, the fourth estimate will be constructed using the (fairly arbitrary) assumptions that half of the firm's government business is perfectly cost-sensitive and half has a cost-sensitivity equal to 0.5. This yields a value for A of

$$A = 0.5[D + 0.5D] . \quad (5.37)$$

Substitution of $D = 0.828$ into Eq. (5.37) yields

$$A = 0.621 . \quad (5.38)$$

The estimates of $\partial\pi/\partial L_i$ derived using values of A of 0.828 and 0.621, will be interpreted as defining a plausible range of possible values for a typical defense firm. The estimates derived using values of A equal to 1 or 0 will be interpreted as defining the theoretical extremes that could occur.

EMPIRICAL ESTIMATION

The parameter values determined in the above subsections can now be substituted into the formulas in Table 5.1. The results of doing this are given in Tables 5.5 and 5.6. Table 5.5 gives the results for $\phi_i(C_i) = 1$ and Table 5.6 gives the results for $\phi_i(C_i) = 0$.

First consider Table 5.5. The marginal impact on profit is positive because the firm wants to increase direct labor on this contract. The effect is largest when $A = 0$ because then each dollar of shifted overhead generates a full dollar of profit. Thus, the first column of Table 5.5 is simply the number of dollars of overhead shifted by a dollar of

company that separately accumulated cost and profit. This is the correct procedure for the purposes of this report.

Table 5.5
The Marginal Impact of Direct Labor on Profit
When $\phi'_i(C_i) = 1$

Case	Value of A			
	0	0.621	0.829	1
Pure waste	1.17	0.44	0.20	0
Labor-material substitution	1.08	0.41	0.19	0
Labor-overhead substitution	2.17	0.82	0.39	0
Subcontracting	0.44	0.17	0.08	0

Table 5.6
The Marginal Impact of Direct Labor on Profit
When $\phi'_i(C_i) = 0$

Case	Value of A			
	0	0.621	0.828	1
Pure waste	-1	-1.72	-1.97	-2.17
Labor-material substitution	0	-0.67	-0.89	-1.08
Labor-overhead substitution	0	-1.35	-1.80	-2.17
Subcontracting	0	-0.27	-0.36	-0.44

direct labor.¹⁰ Then subsequent columns are simply proportionate reductions in the first column as the value of profit per dollar of shifted overhead, $\phi'_i(C_i) - A$, decreases.

Four remarks should be noted about this table. First, the table shows that the incentive effect is extremely large. The two middle columns represent a plausible range of values. For the pure-waste case, for example, the CPPC effect is between 20 percent and 44 percent. That is, burning a dollar and calling it direct labor generates between \$1.20 and \$1.44 of revenue. Second, the incentive effect for labor-material substitution is slightly smaller because material attracts G&A. Thus, the net amount of overhead shifted is smaller. Third, the incentive effect for labor-overhead substitution is much larger because of the extra direct shifting this causes. It is essentially twice the size of the pure-waste case with a plausible range of 39-82 percent. Fourth, the subcontracting distortion incentive is smallest because it occurs only if overhead is fixed. Even in the short run, it was estimated that only 41 percent of the firm's M&E overhead is fixed.

¹⁰This is true even for the pure-waste case, because the second term of the formula, $\phi'_i(C_i) - 1$, equals zero when $\phi'_i(C_i) = 1$.

Thus, the subcontracting incentive distortion equals 41 percent of the labor-material incentive distortion. The plausible range of the CPPC effect is between 8 percent and 17 percent.

Now consider Table 5.6, which creates the same estimates when $\phi'_i(C_i) = 0$. The marginal effect on profit is negative because the firm wants to decrease direct labor use. Most of the same comments regarding the construction of the table and the resulting relationships between columns and rows as made above apply and will not be repeated. Three differences will be noted, however. First, the largest incentive effect now occurs when $A = 1$, since this maximizes the absolute value of $\phi'_i(C_i) - A$. Second, the second term for the pure-waste formula is no longer zero but minus one (i.e., if the firm could reduce direct labor expenditure by \$1 on a commercial contract it would earn \$1 of extra profit). The values reported in the pure-waste row are thus fairly large in absolute value. However, they are not particularly relevant because "negative waste" is not possible. Third, the plausible ranges of the CPPC effects determined by the middle two columns are much larger in Table 5.6 than in Table 5.5. The reason for this is that A is assumed to be closer to one than to zero (A is between 0.621 and 0.828). This means that the incentive effects on the cost-sensitive contract are smaller. However, it also means that the incentive effects on the cost-insensitive contract are larger. In particular, then, a high value of A does not mean that all incentive distortions grow smaller. It simply changes where they occur.

6. DISCUSSION

SIGNIFICANCE OF INPUT SUBSTITUTION DISTORTIONS

One major result of this report is to show that the firm will have the incentive to substitute inefficiently between inputs as well as to pad direct labor. This is significant for three reasons. First, it shows that the incentives identified here can affect a broad range of the firm's decisions involving potentially all aspects of its technology choice. Second, it means that attempting to deal with the problem by auditing is even less likely to be effective, because it is even more difficult for auditors to determine if inputs have been combined in efficient proportions than to determine if labor has been padded. Third, it means that distortions designed to increase revenue on cost-sensitive contracts will not be confined to cost-sensitive contracts. Firms will also have the incentive to purposely underuse direct labor on cost-insensitive contracts.

WELFARE ANALYSIS

This report has settled for simply estimating the magnitude of the marginal incentives to distort input usage instead of continuing on to actually estimate an equilibrium welfare loss. This is because, although fairly reliable and plausible estimates can be created for the size of the marginal incentives, the same cannot be said for estimates of the equilibrium welfare loss. Two additional factors will affect the size of the welfare loss and both of these are difficult to empirically estimate. The first factor is the extent to which auditing can actually restrain inefficiency. The second factor is the marginal rate of substitution between inputs.

If one were to attempt to conduct such a welfare analysis, it would be important to note that two distinct types of losses occur as a result of the firm's direct labor distortions, and depending upon one's point of view, one might want to include one or both of them in assessing the magnitude of the welfare loss. A simple example will make this point clear. Suppose a firm burns \$100 on a defense contract and succeeds in raising the price by \$150 as described in the example in the Introduction. The cost inefficiency equals \$100. The increase in the firm's profit is \$50. The sum of these two terms, \$150, is the increase in the

price paid by the government. From a social point of view the welfare loss is \$100.

The question of greater interest regards the size of the loss to the government. The naive answer is \$150, the size of the price rise. This is, of course, the correct answer in a single-period one-shot analysis. However, in reality the situation is more complex because the DoD and defense firms are involved in a long-term continuing relationship. It is almost certainly the case that the DoD is paying revenues greater than short-run incremental cost on almost all weapons it purchases. Thus, it could almost certainly reduce price in the short run and succeed in still purchasing the same weapons. However, in the long run price must be above long-run incremental cost. Furthermore, joint costs of production must be paid by someone for the firm to exist in the long run. Current arrangements have the DoD pay some share and it is not clear that this share could be reduced without having firms exit. Finally, as I have argued elsewhere (Rogerson, 1989, 1991a, 1991b), it may be that (for incentive-based reasons) the DoD indirectly funds some R&D by purposely paying more than long-run incremental cost on production contracts. Thus, the impact of revenue reductions on R&D must also be considered.

The question of whether a defense firms' revenues from a product are too high or too low relative to the long-run incremental cost of producing the product is really a totally separate question from that of whether costs are too high or too low. This report has been concerned only with the latter question. The former question involves a range of complex issues and is beyond the scope of this report. The point being made here is that there is no reason to simply assume that revenues are too high relative to long-run incremental costs. Therefore, there is no reason to assume that simple transfers from government to the firm represent a welfare loss to government.

Thus, in the absence of any other information, it is perhaps most reasonable to view the government's loss as also being \$100. Generalizing from this example, the government's loss resulting from the incentive problems identified in this report ought to be viewed as equal to the loss resulting from cost inefficiency. In particular, the loss to government should not include simple transfers from government to the firm.

FUTURE TRENDS

Overhead rates in both defense and commercial firms have been rising because of the effects of increased automation. This tends to

lower direct labor costs and increase overhead costs under traditional accounting methods. This trend is likely to continue, which means that the incentive problems identified here are likely to become more severe in the future.

For example, simply extrapolating from historic trends, McCullough and Balut (1990) predict that manufacturing direct labor will be at 27 percent of its current level by the year 2020.¹ Therefore, overhead rates based on manufacturing direct labor would increase by 370 percent (100 percent \div 0.27)! This means that all of the incentive effects identified in this report would be 3.7 times as large.

AUTOMATION

Increased automation reduces direct labor usage and increases both capital usage and indirect labor usage associated with the physical capital. Thus, automation has the effect of decreasing direct labor cost and increasing overhead cost. In particular, then, a prediction of this report is that a defense firm will on average tend to underautomate production of its defense products and overautomate production of its nondefense products. Within its defense products, the extent of underautomation will be most severe on well-funded sole-source programs where competitive pressures are least severe.

It is a well-accepted fact that defense production is underautomated.² Two related explanations have been given for this. The first is that DoD pricing formulas have not fully compensated firms for the true economic cost of facilities capital investment. The second explanation is that defense firms are unwilling to invest in long-lived facilities capital because government is generally unwilling to provide any sort of long-term contractual guarantees. The second argument is of course closely related to the first. If the government refuses to provide long-term contractual guarantees, this increases the risk of investment and thus also increases the required return.

The contribution of this report is to show that there may still be a very significant incentive for firms to underinvest in automation of defense production even if the economic cost of capital investment is being correctly calculated. Section 5 argued that plausible values for the CPPC effect on a cost-sensitive defense product might be between

¹Table 4, p. 13b.

²See DoD (1985), chapter VI, for a good summary of various government policy studies drawing this conclusion. Also, see Gansler (1980), pp. 57-58.

39 percent and 82 percent.³ Thus, even if the regulations succeed in correctly compensating the firm for its true facilities capital cost, the firm will still perceive that it can earn between 39¢ and 82¢ in pure economic profit by substituting \$1 of direct labor for \$1 of facilities capital costs.

This insight perhaps provides an explanation for a puzzling feature of the DoD's most recent adjustment to its formula for calculating a return to defense firms' facilities capital. Because of its concern that defense firms were underautomated, the DoD in 1987 significantly increased the allowed return on facilities capital that it uses to price contracts. As explained in Appendix E, the normal return to facilities capital is now approximately 36 percent. The minimum allowable return is 25 percent and the maximum allowable return is 46 percent. The "puzzle" is simply that these numbers appear enormous. One possible explanation is that they are too large and regulators made a mistake. Another possible explanation is that the risks are extremely large and that the true cost of capital averages 36 percent for defense firms. This report suggests a third explanation. Suppose that there is a significant CPPC effect on direct labor, perhaps on average equal to 40 percent.⁴ Then for defense firms to be indifferent between substituting \$1 of direct labor for \$1 of (annualized) capital cost it would be necessary to pay the firm an interest rate equal to 1.4 times its true cost of capital. In particular, if its true cost of capital were 26 percent, it would be necessary to pay 36 percent to induce it to make the correct capital-labor substitution. Thus, it may be that the very high rates of return in the new policy are truly required to induce firms to make first-best automation decisions. However, this is not because the true cost of capital is this high. Rather, it is because of the input distortion incentives created by the overhead allocation process.

SUBCONTRACTING

The prediction of this report is that a defense firm will keep too much production in-house for its defense products and subcontract too much for its commercial products. Within its defense business, the tendency to keep too much production in-house will be most pronounced for well-funded sole-source procurements, which are subject to the least competitive pressure.

³See Table 5.5.

⁴The calculation reported below is conservative because this value is selected from the low end of the plausible range of 39-82 percent.

This prediction seems broadly consistent with the stylized facts and may explain them better than existing theories. The DoD seems concerned that prime contractors may not make optimal "make-or-buy" decisions and a considerable amount of the DoD's cost-monitoring activity is devoted to reviewing the adequacy of such decisions.⁵ Both Peck and Scherer (1962) and Gansler (1980) suggest that the general concern is that defense firms tend to want to produce too much of their defense products in-house.⁶

Peck and Scherer suggest that in some cases this effect may be explained by the fact that a prime contractor wants to develop expertise in a new area by building a subcomponent itself rather than subcontracting to a firm that already has the expertise. There is undoubtedly some truth to this argument. This report suggests that the incentives for this behavior may be much more general and may not simply apply to the scenario depicted by Peck and Scherer. That is, regardless of any strategic implications for future business, a defense firm may have a strong incentive to reduce subcontracting on its defense business to shift overhead toward it.

Gansler's (1980) explanation for firms' behavior comes closer to that of this report. He states the following.

[I]n defense work profit is directly related to cost, and thus in the defense "make or buy" decision one is faced with the desirability of maximizing cost.⁷

Thus Gansler is essentially positing that CPPC pricing is the source of the problem. However, as argued in the Introduction to this report, the significance of CPPC pricing (if it exists at all) is relatively small. Furthermore, the simple assumption that firms want to increase cost does not provide a particularly compelling explanation for why firms should in particular choose to employ too little subcontracting. For example, employing too much subcontracting would also increase cost. So would employing the optimal level of subcontracting but simply paying higher prices to subcontractors. This report's theory exactly predicts the behavior that occurs. Namely, there will be too little subcontracting of defense products.

Gansler's theory provides an example of the general point made in the Introduction to this report. Many defense analysts believe that de-

⁵See FAR 15.7 for regulations describing this monitoring process.

⁶See Peck and Scherer (1962), pp. 386-391, and Gansler (1980), pp. 132-137.

⁷Gansler (1980), p. 133.

fense firms act as though increasing costs increases their profit. In the absence of any other explanations they have concluded that CPPC pricing must be the problem. This report provides an alternative and more likely explanation of the source of this CPPC effect.

One final remark will be noted about possible distortions involving the subcontracting decision, which steps outside the bounds of the formal model presented here. This concerns the issue of whether there will be a bias in the types of subcomponents that the firm chooses to subcontract rather than make in-house. The formal model does not address this issue because no such choice exists in the model. However, the analysis makes clear that such a bias will exist and could be formally modeled in a straightforward extension. Namely, for its cost-sensitive products, the firm will prefer to keep in-house those subcomponents with high levels of direct material and labor and low levels of overhead costs. The reverse bias will exist for cost-insensitive products. In this case, subcomponents with relatively high overhead costs will be more attractive for in-house production.

The most obvious application concerns the level of automation. Products with more automated production will exhibit relatively higher levels of overhead costs. Therefore, the prediction of this "extended model" is that a firm will bias its make/buy decision on defense products toward subcontracting subcomponents that require more automated production and making in-house subcomponents that require less automated production. The reverse bias will exist for commercial products.

Note that the result of this subcontracting bias is that defense production will be less capital-intensive than commercial production. This result is closely related to the incentives for automation discussed above.

SPARE PARTS

A series of so-called "spare parts pricing scandals" plagued the DoD in the mid-1980s. The story reported was essentially as follows. The price of a relatively common item that individuals might buy at a hardware store for \$10 or \$15 was reported to be thousands of dollars.⁸

⁸See Rasor (1985), chapter 5, for a fairly complete description of a number of these cases. Also see Fitzgerald (1989), chapter 12.

Both critics and supporters of the DoD basically agreed on the following three facts. First, the prices charged and paid generally were equal to fully allocated cost. That is, there was no sense in which defense firms were making money by charging price greater than cost. For example, Fitzgerald (1989) quotes General Ronald Yates, the F-16 program director, as providing the following explanation for spare parts prices during Congressional hearings: "The straightforward answer is that in fact they spent the cost incurred. We knew that."⁹ Rasor (1985) quotes General Dewey Lowe as stating that "The items mentioned were reasonably priced in accordance with rules and regulations."¹⁰

Second, in some cases the high costs were partially explained by the fact that the spare part in question was much more expensive to construct than its hardware store equivalent because of different and more demanding specifications combined with small production runs. Third, in almost all cases, a very large part of the fully allocated cost was overhead allocated in the same fashion as for all of the firm's other contracts.

Of course, critics and supporters of the DoD tended to differ greatly in their interpretation of these facts. First, they disagreed over the necessity of extra requirements that increased cost. This subject will not be discussed further because this report has no new insights to offer. The second disagreement is of more interest here. Supporters tended to view the fact that price equalled cost as proof there was no problem. Regarding overhead costs, they argued that overhead costs are legitimate and spare parts merely picked up their normal share. I think that it is fair to say that critics could offer no explicit intellectually sound counterargument to this view (other than to claim that overhead costs were likely inflated by "fraud, waste, and abuse" and thus were illegitimate costs on *all* contracts including spares).

This report suggests an intellectually sound explanation, and one consistent with the above mentioned facts, of why the overhead allocation process might tend to create both inefficiencies and overly high prices in the procurement of spare parts. In particular it is consistent with the fact that prices charged never exceeded fully allocated costs.

The explanation is that spare-parts contracts are likely in many cases to be very noncompetitive and thus their revenues will be highly cost-sensitive. This is because they occur near the end of a program when

⁹Fitzgerald (1989), p. 215.

¹⁰Rasor (1985), p. 157.

the threat of bringing in a new source is extremely low. Furthermore, government has a fairly great need for the parts to keep the existing fleet operative and the dollar value of the spare parts is relatively low. Thus the contracts will generally be well-funded.

Because of the highly regulated nature of the procurement process, the existence of monopoly power does not necessarily allow defense firms to charge a price greater than cost. In this particular instance it appears that defense firms generally were restricted to charge a price equal to cost. (This is the first agreed-upon fact described above.) However, the key insight of this report is that firms with a large degree of monopoly power will certainly be able to raise their price by a full dollar if their costs go up by a dollar. This is also consistent with the above described facts. (No one, to my knowledge, ever claimed that defense firms were forced to accept a price less than cost on the contracts under scrutiny.)

Therefore, this report predicts that defense firms will have the incentive to purposely overuse direct labor on spare-parts contracts to shift more overhead to these contracts. If this occurs, it will both generate inefficiencies and raise prices.

Many of the published cost breakdowns for spare parts are in fact mildly suggestive that this may have occurred. A very typical example is the cost breakdown reported by Rasor (1985)¹¹ for a hammer whose price was \$436. The firm purchased the hammer for \$9. It then incurred direct labor costs of \$130 in "handling and inspecting" the hammer. Then, \$240 of overhead was allocated to the hammer (\$141 of M&E overhead based on direct labor and \$90 of G&A based on total cost input).¹² Therefore, by incurring \$130 in direct labor the firm succeeded in shifting \$240 of overhead to the contract. One cannot help but wonder if the entire \$130 spent on "handling and inspecting" was truly necessary or if some was incurred solely to shift overhead.

DUAL SOURCING¹³

In weapons programs with moderately large production runs such as missiles, it has become relatively common for the DoD to simultaneously purchase output from two separate suppliers. Cost data are

¹¹P. 165.

¹²In addition, \$56 of profit was paid to yield the price of \$436.

¹³I particularly benefitted from discussions with James Dertouzos in preparing this subsection.

still demanded from the firms. Furthermore, they are still audited and negotiations over price still largely revolve around cost. However, the lower-cost firm is typically given a larger share of the annual buy. Quite typically the lower-cost firm will receive 60 percent of the buy compared with 40 percent for the higher-cost firm. Finally, there is also always the threat looming that a firm that is consistently and significantly higher cost might simply be dropped altogether. Although this situation is a far cry from a perfectly competitive market, it clearly injects an extra element of competition. In terms of this report's paradigm, dual sourcing will make a product less cost-sensitive. A relatively well-accepted fact regarding dual sourcing is that it does seem to cause fully allocated costs to drop (although there is controversy over this).¹⁴

This report supplies a theoretical explanation for this fact. Dual sourcing a program is likely to make it of below-average cost-sensitivity. Because of this, the firm will purposely underuse direct labor and eliminate all possible direct labor waste. This will result in overhead being shifted to other contracts and thus will reduce fully allocated cost.

Traditional procurement analysts have typically accepted a \$1 reduction in fully allocated cost resulting from dual sourcing as representing a \$1 savings to the government. This report clearly identifies the fallacy in this interpretation. First, the bulk of cost reductions may be caused by the reallocation of overhead. If costs are reallocated to other defense contracts there is obviously no total cost savings to the government. Even if the overhead is reallocated to commercial contracts, it is not clear that the government is actually better off.¹⁵ Second, some of the savings in direct labor cost may be caused by firms purposely choosing to use inefficiently low levels of direct labor, perhaps by overusing subcontractors. Thus, not even all of the reductions in direct labor cost represent true cost savings.

Therefore, the major point of this report regarding dual sourcing is that the existing policy debate over whether or not dual sourcing lowers a product's fully allocated costs has ignored the more fundamental questions. Suppose that the DoD dual sources one product that a firm produces. Three relevant questions are:

¹⁴See Pilling (1989) and Anton and Yao (1990) for an empirical analysis and references to other empirical studies. See Drewes (1987) for a fascinating description of a particular procurement where dual sourcing was used. See Anton and Yao (1987, 1989, 1992) for a theoretical analysis.

¹⁵See the discussion above in the "Welfare Analysis" subsection of this section.

1. What is the effect on fully allocated costs summed over *all* DoD products?
2. What is the effect on DoD payments to the firm summed over *all* DoD products?¹⁶
3. What is the effect on fully allocated costs summed over *all* of the firm's products, both DoD and commercial?

Note that question 2 will generally be of more interest than question 1. However, to answer question 2 one needs information on the cost-sensitivities of DoD products. Thus, question 1 may generally be easier to answer, which is why it is included in the above list. Whether question 2 or question 3 is considered to be more important depends on whether one believes that firms' profits ought to be included in a welfare analysis. This is a complicated issue and was discussed above. My own sense is that question 3 is the most important because, in the long run, DoD payments to firms will be lower only if firms' costs are lower.

It is interesting to ask why the DoD uses dual sourcing so extensively if this report's theory is true. A number of relatively mundane explanations are possible. The DoD may simply be wrong. Alternatively, even if this report's theory is true, it may still be the case that the net effect of extra competition is to lower the firm's true total costs and lower the DoD's aggregate payments to the firm. Finally, dual sourcing may serve other goals, such as maintaining reserve capacity.

However, a more fascinating explanation exists. This report has focused on the incentives of profit-maximizing firms and ignored incentives within the DoD bureaucracy. However, overhead allocation has a potentially enormous incentive impact on decisionmakers within the DoD. In particular, individual decisionmakers within the DoD will generally have the incentive to try to minimize the fully allocated cost of the program or programs that they are responsible for. Thus, a program manager within the DoD might quite rationally prefer to use dual sourcing if it lowered his own program's fully allocated costs simply by shifting overhead to other defense programs. At a slightly higher level, an individual military service might well prefer to use dual sourcing so long as the overhead was shifted to programs purchased by other services. Thus, dual sourcing may be the result of a noncooperative overhead shifting game being played by decisionmak-

¹⁶The answers to 1 and 2 may differ because not all DoD products may be perfectly cost-sensitive.

ers within the DoD. The issue of incentive distortions within the DoD will be discussed further in Sec. 8.

EFFORT TO REDUCE DIRECT LABOR

In the formal model of this report analyzing the firm's incentives to incur pure waste of direct labor, it was assumed that the firm could effortlessly reduce direct labor to some minimum level below which it could not fall. In reality, the firm probably must devote resources toward identifying or implementing possible changes that would reduce direct labor use. As direct labor is reduced, the cost of identifying further reductions increases. The purpose of this subsection is to simply point out that the basic results of this report can be easily interpreted and extended to apply to this case as well. Namely, the firm will devote too little (too much) effort toward reducing direct labor cost on cost-sensitive (cost-insensitive) contracts. Two different interpretations of the "effort" variable will be given.

Under the first interpretation, effort consists of extra management supervision or research that generates extra accounting costs allocated to overhead. This case has already been modeled in Sec. 3 as a labor-overhead substitution and thus the desired result follows immediately.

Under the second interpretation, effort once again consists of extra management supervision or research. However, in this case, existing management simply works harder or redirects its attentions. Thus, there is no change in overhead accounting costs. This case has not been formally modeled. However, it is straightforward to add an unobservable effort choice for each product where increased effort lowers direct labor cost. The result is just as expected and will simply be reported. Namely, the firm devotes absolutely no effort to lowering direct labor on cost-sensitive contracts where it wants to increase direct labor. On all other contracts it devotes too much effort to reducing direct labor.

7. POLICY IMPLICATIONS

INTRODUCTION

There are basically two ways to deal with the incentive problems described in this report. The most promising is to increase direct cost allocation to the maximum feasible extent. This is discussed next. The other possible approach is to attempt to directly pay for some joint expenses on a firmwide basis and not to allocate them to products at all. This is discussed below. Finally, this report clearly raises the issue of the desirability of mixed (commercial/government) plant operations. This will be discussed in the final subsection.

MAXIMAL DIRECT ALLOCATION

The defining characteristic of traditional cost-accounting practices used by both defense and nondefense firms is that very little effort is devoted toward directly allocating costs.¹ Thus, many costs currently included in overhead could in principle be allocated directly to products. Perhaps the major policy implication of this report is that greater efforts to directly allocate more costs would be worthwhile because the resulting decrease in overhead rates would reduce the incentive problems identified here. Five remarks will now be noted about this policy approach.

First, there is sharp disagreement in the procurement community over whether increased direct allocation would be worthwhile. The predominant view is that it is not worthwhile. This is certainly the view held by industry and seems to be generally accepted by most of the DoD. The basic argument is that increased direct allocation necessarily requires increased administrative cost and there is no offsetting gain. The major dissenting voice from this view has been the DoD's own auditing group, the Defense Contract Audit Agency (DCAA), which strongly advocates maximal direct allocation. This report presents an explicit theoretical reason supporting the DCAA's point of view. Lower overhead rates are of value in and of themselves because they reduce incentives for inefficient behavior.

¹See Johnson and Kaplan (1988), Berliner and Brimson (1988), and Cloos and McCullough (1989).

Second, current regulations reflect the predominant view that there is no value to direct allocation.² The CAS makes absolutely no explicit requirement to directly allocate as many costs as possible. The closest that it comes to doing this is in CAS 418, which essentially requires that overhead pools be "homogenous." The DCAA has tried to argue that a pool with costs in it that could be directly allocated to different contracts is not homogenous. However, the courts have determined that traditional accounting practices meet the intent of the standard. The *FAR/DFAR* comes closer to requiring this. It defines a direct cost as a cost that *can* be allocated to a single contract, while the CAS defines a direct cost as a cost that *is* allocated to a single contract. The DCAA has attempted to argue that the *FAR/DFAR*, therefore, requires maximum possible direct allocation based on the word "can." However, the courts have not agreed, based upon the interpretation that the CAS has primary authority regarding allocation methods and it uses the word "is," connoting that the contractor has a choice. Perhaps, as well, the courts have been unwilling to create extensive new legal requirements based on a fairly elaborate interpretation of the connotation that might be implied by one word. It is certainly the case that either the *FAR/DFAR* or CAS could easily have been drafted to contain a more explicit requirement if the drafters had desired to do this.

Third, it may be that the new accounting methodologies, often referred to as process-based or activity-based accounting, offer the most significant possibility for reducing overhead rates. The basic methodology involves grouping costs by machine centers and then allocating machine center costs (including all associated labor and computing costs as well as facilities' costs) by machine hours of usage.³

Table 7.1 breaks down M&E overhead for the four aerospace firms considered in Sec. 5.⁴

Facilities-related costs include the rate of return paid for facilities capital as well as depreciation, maintenance, etc. Indirect labor includes associated fringes. Data processing includes only the data-processing costs charged as overhead. This is about one-third of total data-processing costs, i.e., about two-thirds of total data-processing

²Recall that the *FAR/DFAR* and CAS are described in more detail in Appendix A.

³See Johnson and Kaplan (1988), Berliner and Brimson (1988), and Cloos and McCullough (1989) for a more complete discussion and further references.

⁴The same methodology is used to calculate these costs. See Appendix G for a complete discussion.

Table 7.1
M&E Overhead by Cost Type

Cost Type	Cost (\$ thousands)	% of Total
Facilities related	1,124,551	48.5
Indirect labor	715,812	30.9
Data processing	225,895	9.7
Other	252,594	10.9
Total	2,318,852	100.0

costs are currently charged directly. Finally, the major items in the "other" category are travel, tools, and supplies.

The most important conclusion from this table is that the most significant reductions in overhead rates through increased direct charging would occur through direct charging of facilities capital costs. Almost half of the M&E overhead pool consists of facilities' capital costs. Furthermore, it seems possible that significant amounts of both indirect labor and data processing are directly associated with operation of automated facilities rather than with any particular product. If this is true it may be that direct charging of facilities would also be required to directly charge these associated costs. This is why activity- or process-based costing may be an extremely important methodology for increasing direct charging.

It is not clear, however, that process- or activity-based accounting offers a complete panacea, because at least some of the costs of machine centers are in all likelihood joint (i.e., there are economies of scope). Thus, using machine hours to allocate these costs may create essentially the same problem as currently occurs when direct labor is used to allocate joint costs, i.e., firms may have the incentive to purposely overuse machine centers on their cost-sensitive contracts. This complex question involves a number of theoretical and empirical issues and is beyond the scope of this report. It requires explicit consideration of factors such as long-run compared with short-run incentives, excess capacity, and whether machine hours of usage can be easily "padded" or not. (I intend to explicitly study the incentive effects of process- or activity-based accounting in a future report.) A reasonable "provisional" conclusion is that it is a promising methodology but that possibly significant questions regarding it need to be investigated.

Fourth, it may be that more modest efforts to simply increase direct costing within the traditional framework may also have a significant impact. This is particularly true of efforts to increase direct charging

of labor because of the double impact this has on reducing overhead and also increasing the base. For example, suppose that one-half of indirect labor could be directly charged. Using the data in Tables 5.2 and 7.1 it is straightforward to calculate the new M&E overhead rate. The rate drops from 0.99 to 0.73. Thus, the magnitude of the various incentive problems would be reduced by approximately 25 percent. Suppose, in addition, that one-half of the data-processing and other overhead costs could also be directly charged. Then the M&E overhead rate would fall to 0.64.

Fifth, as industry has correctly argued, increased direct charging of costs would require greater recordkeeping expense. Thus, before implementing any policy changes, it would be important to attempt to estimate both the marginal costs and the benefits of increased direct charging. Johnson and Kaplan (1987) argue that recordkeeping costs have declined dramatically because of the increased use of computers. This is an empirical issue that could be fairly easily quantified.

To conclude this subsection, three possible policy approaches to increase direct charging will be discussed. The first is simply to create a new cost-accounting standard that requires more direct costing. Although this approach superficially appears reasonable it may, in fact, exhibit some problems. In particular, because recordkeeping has costs, it probably is true that the optimal amount of direct charging is less than the maximum possible amount. It is not immediately clear how one could structure a regulation that requires the optimal amount of direct charging. Judging by historic behavior patterns, it is reasonable to conjecture that audit and enforcement agencies within the DoD might well use a regulation requiring increased direct allocation to literally require direct allocation of all possible expenses regardless of cost. The courts would then be forced to decide what level of direct allocation was required and there is no reason at all to believe that the courts would make an appropriate decision on a technical issue of this sort. A related problem is that the optimal nature and amount of direct costing might well vary from firm to firm, depending on the nature of their production processes, product mix, etc. It may be difficult to design regulations that specifically require direct costing but still allow flexibility to respond to individual circumstances.

A second policy approach designed to finesse these difficulties would be to attempt to provide firms with the incentive to charge more costs directly. Government could affect the overall level of direct costing by changing the level of incentives, but each firm could still decide the optimal nature of its own response given its individual circumstances.

This could be accomplished by paying a small increment on direct costs and a small decrement on indirect costs. For example, suppose that a firm charged 60 percent of its costs directly and 40 percent indirectly in a given year. Then, for contracts signed the next year the government could purposely multiply direct cost by $(1 + x/0.4)$ and multiply indirect cost by $(1 - x/0.6)$ to calculate price. The value of x would probably be chosen to be quite small, perhaps 0.004. Thus, government would add 1 percent to direct costs and subtract 0.67 percent from indirect costs. If the firm could charge more costs directly it would earn a small profit for one year.

The third possible policy approach involves the procedures currently in place to deal with a firm's changes in its accounting system. Under the CAS, a firm must file a complete description of its accounting practices with the DoD. If the firm changes any practices, it must formally report this change. At this point the DoD calculates the "cost impact" of the change on existing DoD contracts. If the costs to the DoD are calculated to rise then the firm must refund this amount to the DoD. The rules for calculating the cost impact are largely correct and will not be described here. They basically prevent contractors from "gaming" the system by changing accounting systems after they sign contracts to shift costs away from existing fixed-price contracts onto existing cost-type contracts. For the purposes of this report the point is that it might be a reasonable policy for the government to allow one-time exceptions to this rule, negotiated case by case, for firms that want to implement major changes in their accounting systems designed to increase direct charging. This would essentially provide another financial incentive for firms to increase direct charging and remove some uncertainty associated with the change.

DIRECT PAYMENT FOR JOINT EXPENSES

The ideal accounting system would calculate direct cost for each product equal to long-run incremental cost. The remaining costs are, by definition, joint costs. The DoD's current practice is to allocate these costs to products. If these costs are allocated to defense products and if price is sensitive to accounting cost on these products, the DoD will then pay for a share of these joint costs. The major point of this subsection is that an alternative method of paying for these joint costs would be for the DoD to directly negotiate payments on a firmwide basis and for no allocation to individual products to occur.

The major problem with such an approach is that there is no objectively verifiable way of disentangling many joint costs from long-run

incremental costs. This problem applies to almost all joint costs occurring at the manufacturing level (as opposed to the central management level). There are probably two major sources of joint costs within the manufacturing process. The first is economies of scope. The second is excess capacity not needed for current production but which is (presumably) needed for potential future production. Both phenomena result in the sum of long-run incremental costs for current products being less than total cost. However, there is probably in general no objectively verifiable method for measuring either of these.

The implication of this is that the methodology of directly paying for joint expenses may only be of practical importance for G&A expenses and IR&D/B&P expenses.⁵ Conceptually, these are clearly joint expenses and can be separately identified in an objectively verifiable fashion. (They already are.)

Each of these two cases raises slightly different issues so each will be discussed in turn. After discussing each case separately, this subsection will conclude by estimating the change in incentives that would occur if both these costs were directly paid.

G&A

Under the proposed method, before the beginning of each year, DoD representatives and the firm would agree to a contract governing the firm's G&A reimbursements for the upcoming year. Payments would be made directly to the firm and not be attached to any product. The contract could be a "fixed-price" contract or might involve some cost-sharing. It may be that G&A expenses are predictable enough that a fixed-price-type arrangement where government makes a fixed direct payment regardless of *ex post* costs would be desirable.

A major problem that may limit the effect of this change regards how the DoD will determine the share of the G&A it is willing to pay when the firm has both government and commercial business. The inevitable tendency (and perhaps the only possible solution) might be for the DoD to pay for a share equal to its share of the firm's total business. Of course, there is no way to measure this other than by using the share of direct labor or total cost input employed on DoD

⁵In previous sections, IR&D/B&P expenditures were viewed as a subcomponent of G&A expenditures, since for purposes of calculating overhead rates, they were the same. In this section it will be useful to separately distinguish these costs, since different issues arise when contemplating directly paying for them. Thus, the term G&A will be interpreted as not including IR&D/B&P.

contracts. The problem with this is that it preserves precisely the incentives that are not wanted. Namely, the firm can increase the share of its G&A that is reimbursed by engaging in input distortions.

Two remarks should be noted about this problem. First it does not mean that direct payment of joint costs will have no desirable effects. Many of the undesirable incentives of the current system are created by firms' attempts to shift overhead between defense contracts. All of these problems would be solved. Second, one possible solution for firms with only "moderate" levels of commercial business would be for government to simply view 100 percent of the G&A expenses as legitimate costs. One possible related policy change could be to require firms to exclude purely commercial expenses from the G&A pool (such as commercial selling expenses). It may be that, on average, 100 percent of the remaining expenses is approximately equal to the DoD's previous share of total G&A. No publicly available data are available on this issue but information could obviously be gathered.

The major danger of adopting the policy of direct payment for G&A is that this somehow might cause the DoD to decide to quit paying for it. In the short run, the DoD could probably pay for no G&A and still purchase the weapons it desires. However, in the long run, firms stay in business only if all of their joint costs can be covered. The proposed system would require separate appropriations for G&A expenses. Perhaps there would be a danger that either Congress or the DoD itself would somehow then be more tempted to not pay for these "unproductive" costs. The fact that there might be no short-run consequences would increase the danger. The current system does not allow the DoD or Congress to easily single out G&A expenses. Whether this "protective linkage" with all other costs is truly desirable or not is not clear. However, it is an important issue that would need to be considered before implementing this change.

IR&D/B&P

IR&D expenditures are expenditures on research and development independently conducted by the firm (i.e., not required by any contract) and for which the firm receives all resulting patent rights, etc. B&P expenditures consist of expenditures by the firm in preparing, submitting, and supporting bids and proposals on government and nongovernment contracts.

The current procedure for government subsidization of these expenditures is basically as follows.⁶ Before the beginning of each year the DoD negotiates an IR&D/B&P ceiling with each firm. Then in the upcoming year IR&D/B&P expenditures up to the ceiling level are considered as legitimate costs for purposes of government contract pricing. The IR&D/B&P costs are allocated to individual contracts using the same allocation base as G&A.

For example, suppose that a ceiling of \$1 million is negotiated with a firm. During the year the firm spends \$1.5 million on IR&D/B&P and 70 percent of its total cost input is for DoD business. Then 70 percent of \$1 million, or \$700,000 will be allocated to DoD contracts. The firm will recover some share of the \$700,000 depending on the cost-sensitivity of its contracts. Note that in general it is probably not known with any precision what fraction of the \$700,000 the firm actually receives. Furthermore, the fraction recovered may vary widely from firm to firm or from year to year within the same firm.

The policy approach suggested by this report is to replace this procedure with a subsidy paid directly to the firm and negotiated at the start of each year. For example, the DoD might agree to pay 70 percent of the first \$1 million of expenditures of the firm. Then over the year the DoD would directly pay the firm 70¢ every time that \$1 of IR&D/B&P expense was incurred until \$1 million of expenditures was incurred. One could obviously imagine more complicated variants. The result of this policy change would be that overhead rates would decrease and thus the incentive problems identified by this report would diminish.

Four remarks will now be noted about this policy approach. First, directly paying for IR&D/B&P is a vastly superior method to that currently used even if one ignores the effect on overhead rates. This is because the current convoluted process makes it almost impossible to know how much of a subsidy is being paid to any particular firm. Furthermore, the subsidy will vary in uncontrollable ways among firms and within the same firm over time. A system that allowed one to explicitly choose both the marginal rate of subsidy and the total subsidy offers obvious advantages.

Second, the only possible advantage of the current system is that it may result in less Congressional or DoD influence on firms' decisions as to what types of programs to undertake. One rationale for IR&D

⁶See Alexander, Hill, and Bodilly (1989) for a much more detailed description of the institutions.

subsidies is to encourage firms to independently develop their own approaches and ideas without excessive government guidance and thus generate a wider variety of research than if the DoD directly funded all R&D through contracts. Thus, one might argue that increasing Congressional or DoD influence would be negative. The reason that the current system may result in less Congressional or DoD influence is that no money is ever actually appropriated or directly paid for IR&D. One might argue that if Congress began appropriating money directly for subsidies, more oversight and formal reporting requirements would be the inevitable result. This argument is suggested by Alexander, Hill, and Bodilly (1989).⁷ However it is by no means clear that this argument is valid. In principle, exactly the same level of independence could be maintained. Furthermore, Congress has to approve the annual ceiling levels of IR&D/B&P under the current system and the DoD directly negotiates the ceilings. It is not clear why the opportunities for control would be that much greater under a subsidy system. In conclusion, there is only one possible disadvantage to adopting the proposed policy approach and it is by no means clear that it would be significant.

Third, the problem raised for the G&A case of determining an appropriate share for the DoD to pay when the firm engages in both government and commercial business does not arise. Regarding IR&D expenditures, DoD personnel already evaluate proposed research projects for potential military relevance when deciding how large a ceiling to negotiate with each firm. Regarding B&P expenditures, the obvious solution would be to include B&P expenditures only on DoD programs. Thus, there is no reason for the DoD to attempt to base payments for IR&D/B&P on the share of total cost input employed on DoD contracts.

Fourth, there is currently a very large policy controversy over whether IR&D/B&P subsidies are too large or not. The debate focuses on whether, and to what extent, these subsidies cause firms to increase their research expenditures.⁸ This debate is basically on a different issue than that considered here. The debate is over the appropriate size for the total and marginal subsidy to IR&D/B&P. The point of this report is that given any desired total and marginal subsidy, it is optimally given to firms through direct payments instead of through overhead pools.

⁷P. 29.

⁸See Alexander, Hill, and Bodilly (1989), Brock (1990), and Lichtenberg (1990).

Magnitude of Incentives

This part will calculate the change in overhead rates that would occur if IR&D/B&P or G&A were directly paid. The calculations will be made using the data for the four aerospace firms as presented in Sec. 5 and Appendix E. From Table 5.2, G&A/IR&D/B&P expenditures were 8.1 percent of total cost. From Appendix E, Table E.7, this can be broken down into G&A expenditures of 5.6 percent and IR&D/B&P expenditures of 2.5 percent.

It is straightforward to calculate new values of D if one or both of these two expenditures were paid directly. These are presented in Table 7.2. Recall that D is the number of dollars of overhead shifted by \$1 of direct labor. Reductions in D essentially cause proportionate reductions in the magnitude of incentives to distort direct labor.

The major conclusion to be drawn from Table 7.2 is that direct payment for G&A and IR&D/B&P would have only a moderate impact on the magnitude of incentive distortions. Direct payment of both costs would reduce D from 1.17 to 0.99, which is a 15 percent reduction. This mild reduction reflects the fact that most overhead is in the M&E pool and that G&A/IR&D/B&P is allocated over total cost input, which reduces distortionary incentives

MIXED PLANT OPERATIONS

Many defense contractors are extremely large diversified companies with multiple divisions engaged in different types of business. Each division is typically a separate accounting entity. Production for the DoD will typically be concentrated in one or more "government products" divisions. However, many defense firms will typically produce at least some commercial products within their government products divisions. In its last major statistical survey of defense contractors, the DoD found that government products divisions of major defense

Table 7.2
Values of D If G&A or IR&D/B&P
Were Directly Paid

Case	Value of D
Neither directly paid	1.17
IR&D/B&P directly paid	1.10
G&A directly paid	1.04
Both directly paid	0.99

contractors averaged 82.8 percent DoD business and 17.2 percent commercial business.⁹ This figure can vary widely between firms. General Dynamics, for example, produces almost entirely DoD products. Boeing, on the other hand, produces significant amounts of both defense and commercial products within the same divisions of the company.

A correct conclusion to draw from this report is that the incentive to increase direct labor use on DoD contracts will be greater when the amount of commercial business within a division increases. If this was the only effect of mixing government and commercial business, then it would follow that government ought to discourage this practice. However, there are probably a number of relatively large advantages to this mixing of business types and it may well be that the advantages outweigh the disadvantages. Attempting to make this evaluation is beyond the scope of this report. The point being made here is simply that it is by no means clear that government ought to discourage mixed plant operations. It may be that the optimal policy is to encourage or at least allow mixed plant operations and to pursue the other policy approaches outlined above to ameliorate the undesirable incentive effects.

This part concludes with a list of possible advantages of mixed plant operations. First, there may well be economies of scope and scale that can be taken advantage of. One often-cited economy results because defense and commercial business demand is often uncorrelated. Thus, by engaging in both, a firm may be able to smooth input usage and produce at lower cost. Second, it is often argued that incentives to operate efficiently generated by commercial activities can spill over into a firm's defense work. Third, it may be that productive capacity employed on commercial production within a government products division may be more easily switched to DoD production than would productive capacity in a purely commercial division. If so, mixed plant operations might create reserve capacity for DoD production.

⁹DoD (1985).

8. DISTORTIONS IN DOD DECISIONMAKING

This report has focused on distortions in defense firms' decisionmaking. However, current overhead allocation practices will also tend to distort internal decisionmaking within the DoD. This final section briefly explains why this is so. (I intend to analyze this issue more thoroughly in a future report.) However, an important preliminary conclusion, drawn below, is that the two policy approaches suggested in Sec. 7 (greater direct costing, direct payment for joint costs) will also tend to ameliorate incentive distortions within the DoD bureaucracy.

The basic reason that current overhead allocation practices distort internal DoD decisionmaking is that individual decisionmakers within the DoD will generally have the incentive to try and minimize the fully allocated cost of the program or programs that they are responsible for. However, this will in general not minimize the cost to the entire DoD, because one very effective way to minimize the fully allocated cost of a program is to shift overhead to other programs. Thus, individual program managers will value cost reductions that arise solely because overhead is shifted to other programs. Military services will value cost reductions caused by overhead shifting so long as the overhead is shifted to programs purchased by a different service. Thus, individual decisionmakers within the DoD may be involved to some extent in a noncooperative overhead-shifting game.

One important example of this phenomenon may be dual sourcing. This was discussed in Sec. 6. Another example concerns a program manager's decision as to which costs to monitor most closely. He will obviously have a disproportionately large incentive to monitor direct labor costs as opposed to costs accumulated in overhead pools. Finally, individual program managers or services may avoid placing contracts with firms exhibiting a large amount of excess capacity desired by some other program manager or service.

There are two different approaches to solving this problem. The first is to reduce the incentives of individuals to make distorted decisions. It is clear that greater direct costing and greater direct payment of joint expenses will tend to accomplish this.

The second approach is to attempt to institute procedures that allow more centralized oversight. The source of the problem is that decisionmakers at lower levels may not fully internalize the effects of

their decisions on other parts of the organization. Thus one possible solution would be for central authorities (who internalize more of these external effects) to exercise more oversight. Complete oversight is impossible, of course. This is why delegation occurs in the first place. Nevertheless, oversight has some effect and its effect is likely to be greater if it is easier for central authorities to gather, process, and understand the relevant information. It is fair to say that central decisionmakers in the DoD or Congress rarely are presented with any data other than fully allocated accounting cost. Thus, greater direct costing would improve the situation because fully allocated cost would tend to be closer to long-run incremental cost. However, more radical changes in the form of budget information that made the nature of the external effects more transparent might also be useful.

Finally, it should be noted that the issues raised in this section are very analogous to those raised by proponents of activity- or process-based accounting for commercial firms.¹ A commercial firm is a large complex bureaucracy much as the DoD is. Therefore the same two problems of distorted incentives and inadequate information for central authorities arise. Increased direct costing is seen as a solution to both these problems for the same reasons as for the DoD case.

¹See Johnson and Kaplan (1988).

Appendix A

AN OVERVIEW OF REGULATIONS GOVERNING COST CALCULATIONS

This appendix will briefly describe the regulations governing the way that defense contractors calculate the cost of their products. Readers desiring more detail might refer to two excellent nontechnical overviews by Grenough (1984) and Grenough and Shapiro (1983).

Basically, two bodies of regulations govern the way that defense contractors calculate the cost of their products. These are, first, the *Federal Acquisition Regulations (FAR)* and the *Defense Federal Acquisition Regulations (DFAR)* and, second, the *Cost Accounting Standards (CAS)*. The *FAR* and *DFAR* are designed to completely describe all regulations governing the procurement process. The *CAS* specifically addresses the cost-allocation methods used by defense firms.

Before 1984 the various branches of the federal government each had completely separate sets of regulations governing their procurement processes. In 1984 the *FAR* was published as a general set of regulations governing the procurement process of all government agencies. These are published as Chapter 1 of Title 48 of the *Code of Federal Regulations*. Each government agency also publishes a supplementary set of regulations that are consistent with the *FAR* but describes in more detail aspects of procurement of particular interest to that agency. The DoD supplement is called the *DFAR*. It is published as Chapter 2 of Title 48 of the *Code of Federal Regulations*. The general regulations contained in the *FAR* are extremely detailed and a very large fraction of the DoD's procurement process is in fact determined by the *FAR*. It should also be noted that the *FAR* and *DFAR* perform two functions. First, they specify the required behavior of contractors. However, second, and just as important, they specify the required behavior of the DoD.

In 1970, the DoD's procurement practices were still governed by the predecessor to the *FAR* and *DFAR* called the *Armed Services Procurement Regulations*. The *ASPR* contained essentially no regulations governing the way that contractors allocated costs. In Congressional hearings examples were presented showing how contractors manipulated their allocation methods to increase government contract costs. For example, contractors would charge a cost directly

when it was incurred for a government contract but would charge the same type of cost to overhead when it was incurred for a commercial contract. Congress's response was to create the Cost Accounting Standards Board (CASB) in 1970 whose purpose was to create a set of regulations designed to prevent this type of manipulation.

The CASB issued 19 standards on different aspects of the allocation process. They are published in Title 4 of the *Code of Federal Regulations* and are usually referred to as standards 401 through 420, since this is the numbering used for them in the *Code of Federal Regulations*. (There are only 19 standards. Number 419 was left unfilled.) These standards have the force of law through the enacting legislation and are not merely administrative regulations. The standards do not attempt to define a single cost-accounting system that must be used by all firms. Instead, they describe fairly general principles designed to prevent fraudulent manipulations. For example, CAS 402 prevents the manipulation described above by requiring that like costs in like circumstances be allocated the same way. A fairly accurate description of the CAS is that its goal is to force contractors to use the same type of allocation methods that they would use if they were purely commercial and their prices were not cost-based.

The CASB's recent history has been somewhat tumultuous. In 1981 the board ceased to exist because Congress did not appropriate funds for it. However, the CAS continued to exist and have the force of law. In 1990 the CASB was reconstituted and it will presumably now continue to revise existing standards or issue new ones.

Note that the CAS was originally created to fill a void in the general set of regulations now called the *FAR/DFAR*. However, at the time, the DoD could certainly have issued regulations governing firms' allocation practices if it wished. After creation of the CASB there was therefore a possibility of conflicting regulations. Courts soon resolved this potential conflict by deciding that the CAS controlled *allocability* whereas the *FAR/DFAR* controlled *allowability*. Allocability is defined as procedures determining how costs will be allocated between contracts. Allowability is defined to be rules determining whether costs will be considered as legitimate or not by the DoD for purposes of costing. The practical impact of this is that the DoD can still wield a sort of "veto power." If the DoD does not like the way that the CAS allows a particular cost to be allocated then it can simply make the cost unallowable. This type of behavior has been fairly typical. For example, the CAS has been interpreted as allowing commercial advertising expenses to be included in G&A and allocated over all con-

tracts. DoD's response was to make these costs largely unallowable. This has the same impact as regulations requiring them to be allocated to commercial contracts.

Appendix B

THE PURE WASTE MODEL

The first-order conditions for Eqs. (4.6) to (4.7) are

$$\frac{\partial \Gamma}{\partial L_i}(L^*) = 0 \text{ and } L_i^* \geq L_i^F. \quad (\text{B.1})$$

$$\frac{\partial \Gamma}{\partial L_i}(L^*) < 0 \text{ and } L_i^* = L_i^F. \quad (\text{B.2})$$

From Eq. (3.6) rewrite $\partial \Gamma / \partial L_i$ as

$$\frac{\partial \Gamma}{\partial L_i}(L^*) = (1+R)\phi_i'(C_i^*) - (1+RA). \quad (\text{B.3})$$

In particular, then, the terms

$$\left\{ \frac{\partial \Gamma}{\partial L_i}(L^*) \right\} \quad (\text{B.4})$$

and

$$\left\{ \phi_i'(C_i^*) \right\} \quad (\text{B.5})$$

are ranked in the same order. Proposition 3 follows immediately from this.

Now consider Proposition 4. Suppose (for contradiction) that

$$L_i^* > L_i^F \quad (\text{B.6})$$

for every i . Then by Eq. (B.1),

$$\frac{\partial \Gamma}{\partial L_i}(L^*) = 0 \quad (\text{B.7})$$

for every i . Therefore $\phi'_i(C_i^*)$ must be equal for every i . Call this common value x . Note that A is therefore also equal to x . Substitution into Eq. (B.3) yields

$$\frac{\partial \Gamma}{\partial L_i}(L^*) = x - 1. \quad (\text{B.8})$$

Since Eq. (B.8) must equal zero, then $x = 1$. This contradicts Eq. (4.3).

Now consider Proposition 5. It is obviously sufficient to prove that

$$\phi'_i(C_i^*) < 1 \quad (\text{B.9})$$

for every i . Suppose (for contradiction) that

$$\phi'_k(C_k^*) = 1 \quad (\text{B.10})$$

for some k . Then Eqs. (B.1) to (B.3) imply that

$$\phi'_i(C_i^*) = 1 \quad (\text{B.11})$$

for every i , contradicting Eq. (4.3).

Appendix C

THE INPUT SUBSTITUTION MODEL

First two lemmas will be stated that more clearly define what needs to be proven. Since the proofs of the lemmas are straightforward, they will not be given.

Lemma 1 states that if the labor choice is too large (too small) relative to both second-best criteria, then the labor choice is also too large (too small) relative to the first-best criterion.

Lemma 1:

Consider a vector of inputs (L_i, M_i, Z_i) which satisfies

$$L_i = f^i(M_i, Z_i) . \quad (C.1)$$

Suppose that

$$L_i > (= ; <) L_i^s(M_i) \quad (C.2)$$

and

$$L_i > (= ; <) L_i^s(Z_i) . \quad (C.3)$$

Then

$$L_i > (= ; <) L_i^F . \quad (C.4)$$

The significance of this lemma is that it means that Proposition 6 follows directly from Proposition 7. Therefore, it is sufficient to prove Proposition 7. Note that the only role of assumption (g) in the proof is to guarantee that Lemma 1 is true.

Lemma 2 now establishes conditions that determine whether L_i is too large or too small relative to both second-best criteria.

Lemma 2:

Consider a vector of inputs satisfying Eq. (C.1). Then

$$L_i \underset{<}{=} L_i^*(M_i) \Leftrightarrow f_M^i(M_i, Z_i) \underset{>}{=} 1 . \quad (C.5)$$

$$L_i \underset{<}{=} L_i^*(Z_i) \Leftrightarrow f_Z^i(M_i, Z_i) \underset{>}{=} -1 . \quad (C.6)$$

Therefore, it is sufficient to prove the following two statements:

$$\phi_i(C_i) \underset{<}{=} A^* \Leftrightarrow f_M^i(M_i^*, Z_i^*) \underset{>}{=} -1 . \quad (C.7)$$

$$\phi_i(C_i) \underset{<}{=} A^* \Leftrightarrow f_Z^i(M_i^*, Z_i^*) \underset{>}{=} -1 . \quad (C.8)$$

Substitute Eq. (4.12) into $\Gamma(L, M, Z)$ so that profits are a function of M and Z . Denote this function as $G(M, Z)$. The first-order conditions for the firm's optimization problem are then

$$\frac{\partial G}{\partial M_i}(M^*, Z^*) = 0 \quad (C.9)$$

and

$$\frac{\partial G}{\partial Z_i}(M^*, Z^*) = 0 . \quad (C.10)$$

It will now be shown that Eq. (C.9) implies Eq. (C.7) and Eq. (C.10) implies Eq. (C.8).

First, consider Eqs. (C.7) and (C.9). Rewrite Eq. (C.9) as¹

¹The function f^i and its derivative are evaluated at M_i^*, Z_i^* . That is, f^i denotes $f^i(M_i^*, Z_i^*)$, f_M^i denotes $f_M^i(M_i^*, Z_i^*)$, etc. This convention will be used throughout the appendix.

$$\frac{f_M^i \left(\sum_{k=1}^n Z_k^* + J \right)}{\sum_{k=1}^n f^k} \left\{ \phi_i'(C_i^*) - A^* \right\} + (f_M^i + 1) \left\{ \phi_i'(C_i^*) - 1 \right\} = 0. \quad (C.11)$$

By assumption, f_M^i is negative and $\{\phi_i'(C_i^*) - 1\}$ is nonpositive. Therefore, there are two cases to consider. First, suppose that

$$\phi_j'(C_j^*) = 1 \quad (C.12)$$

for some j . Then, by Eq. (C.11),

$$A^* = 1. \quad (C.13)$$

Since the average value of the derivatives is 1 and no derivative can be greater than 1, this implies that all derivatives equal 1. That is,

$$\phi_i'(C_i^*) = 1 \quad (C.14)$$

for every i . This contradicts Eq. (4.3). Therefore, the first case cannot occur.

In the second case

$$\phi_i'(C_i^*) < 1 \quad (C.15)$$

for every i . In this case Eq. (C.11) immediately implies Eq. (C.7).

Now consider Eqs. (C.8) and (C.10). Rewrite Eq. (C.10) as

$$\left\{ \frac{f_Z^i \left(\sum_{k=1}^n Z_k^* + J \right)}{\sum_{k=1}^n f^k} - 1 \right\} \left\{ \phi_i'(C_i^*) - A^* \right\} + (f_Z^i + 1) \left\{ \phi_i'(C_i^*) - 1 \right\} = 0. \quad (C.16)$$

Since f_Z^i is negative, the entire term

$$-\frac{f_Z^i \left(\sum_{k=1}^n Z_k^* + J \right)}{\sum_{k=1}^n f^k} - 1 \quad (\text{C.17})$$

is negative. The proof that Eq. (C.17) implies Eq. (C.8) now parallels the proof that Eq. (C.11) implies Eq. (C.7). Q.E.D.

Appendix D

THE SUBCONTRACTING MODEL

Because the cost function (4.31) is single peaked, the question of whether labor usage is greater or smaller than the first-best can be investigated by determining the derivative of the cost function. That is,

$$L_i^* \begin{matrix} > \\ < \end{matrix} L_i^F \Leftrightarrow 1 + g_i'(L_i) + h_i'(L_i) \begin{matrix} > \\ < \end{matrix} 0 . \quad (D.1)$$

Recall that $\pi(L)$ denotes the value of $\Gamma(L, M, Z)$ when Eqs. (4.35) and (4.36) are substituted into Γ . Therefore, the first-order conditions are

$$\frac{\partial \pi}{\partial L_i}(L^*) = 0 . \quad (D.2)$$

From Eq. (3.15) this is given by

$$\left[R^* - g_i'(L_i^*) \right] \left[\phi_i'(C_i^*) - A \right] + \left[1 + h_i'(L_i^*) + g_i'(L_i^*) \right] \left[\phi_i'(C_i^*) - 1 \right] = 0 . \quad (D.3)$$

Now consider case (i) of Proposition 8. Assume that

$$R^* - g_i'(L_i^*) > 0 . \quad (D.4)$$

Just as in Appendix B, it must be that

$$\phi_i'(C_i^*) < 1 . \quad (D.5)$$

(If $\phi_i'(C_i^*) = 1$ for some i , then $\phi_i'(C_i^*) = 1$ for every i , which contradicts Eq. (4.3).) The result now follows from Eqs. (D.3) and (D.1). The proofs of (ii) and (iii) are very similar.

Appendix E

DERIVATION OF TABLE 5.2

Table E.1 presents the raw data on cost pools obtained from McCullough and Balut (1990). These are the total dollar figures summed across all four firms for the year 1987.¹ Direct labor and overhead are obtained from their Table 3, p. 10. The figure for total cost (which is called the total business base) is obtained from their Table 2. Then, material is determined as a residual. Note that material includes the cost of all subcontracts and, as well, any direct charges that are not material or direct labor. These are usually called "other direct charges" (ODCs). The largest ODC is directly charged computer costs. For the purposes of this report there is no need to separate material and ODCs. Therefore, they are all simply included under the category labeled direct material.

The derivation of the totals for the various components of overhead is slightly more complicated. In their Table 14, overhead is broken into the four categories of engineering, manufacturing, material, and G&A. Summing manufacturing and engineering together yields the three categories reported in Table E.1. However, one further correction must be made. The direct labor and direct material figures in Table E.1 include direct labor and material charged to IR&D/B&P. However, the M&E overhead pool reported in McCullough and Balut's Table 14 also includes these figures. Therefore, they must be subtracted from one or the other to avoid double-counting. In

Table E.1
Raw Data

Cost Pool	Cost (\$ thousands)
Direct labor	1,897,060
Direct material	5,786,010
Overhead	3,509,127
G&A	650,006
Material	281,157
M&E	2,577,964
Total	11,192,197

¹All dollar figures in this appendix are in thousands of 1987 dollars.

Table E.1 they have been subtracted from M&E overhead. The direct IR&D/B&P charges total \$199,117.²

Because the data in Table E.1 are not suitable for the purposes of this report for several reasons, they will now be transformed in six steps into a suitable form. Each step will be explained individually.

STEP 1: FULLY LOADED IR&D/B&P

Government regulations³ specifically require the following accounting treatment of IR&D/B&P costs. Direct labor and material are charged to individual IR&D or B&P projects as though they were a contract. Then all overhead pools *except* G&A are allocated over contracts and IR&D/B&P projects. Finally, these "fully loaded" IR&D/B&P costs are allocated to contracts using the same allocation base as G&A.

For purposes of this report, the important figure to calculate is the value of "fully loaded" IR&D/B&P costs. These will then be viewed as a separate element of overhead allocated using the same base as G&A.⁴ In Table E.1, the direct labor and direct material charged to IR&D/B&P is included in direct labor and material. In a personal communication, J. McCullough stated that the total IR&D/B&P direct charges of \$119,117 were approximately 80 percent direct labor and 20 percent material or ODCs. This yields values of \$159,294 for direct labor and \$39,823 for direct material. The material overhead rate is 0.0486 ($281,157 \div 5,786,010$). The labor overhead rate is 1.3589 ($2,577,964 \div 1,897,060$). Applying these overhead rates to the IR&D/B&P direct material and direct labor yields "full loaded" IR&D/B&P costs of \$417,517. This is reported in Table E.2. The overhead and direct charges assigned to IR&D/B&P have been subtracted from the relevant pools.

²This figure is from McCullough and Balut's Table 10. I am grateful to James McCullough for explaining the required correction to me.

³CAS 420.

⁴This treatment will ignore one technical point that has no substantive effect on the calculations. In reality, if direct labor use changes on any contract, then this changes the overhead rate and thus also changes the value of "fully loaded" IR&D/B&P. However, this effect is extremely small so it will be ignored, i.e., the value of "fully loaded" IR&D/B&P will be viewed as a constant not affected by direct labor usage.

Table E.2
The Result of Step 1

Cost Pool	Cost (\$ thousands)
Direct labor	1,737,766
Direct material	5,746,187
Overhead	3,708,244
G&A	650,006
IR&D/B&P	417,517
Material	279,222
M&E	2,361,499
Total	11,192,197

STEP 2: ALLOWABLE IR&D/B&P

An additional complication also exists with regard to IR&D/B&P expenses: The DoD accepts only a certain amount of IR&D/B&P expenses as "allowable" for generating costs that it will recognize in pricing defense contracts. All large firms negotiate a dollar value ceiling with the DoD each year. IR&D/B&P expenses up to the ceiling are then allowable for defense contract costing. Furthermore, the ceiling almost always is binding, i.e., total IR&D/B&P expenditures are almost always greater than the ceiling. Note that the ceiling applies to total IR&D/B&P expenses and not to the DoD's share. For example, suppose a firm spends \$1.5 million on IR&D/B&P, its negotiated ceiling is \$1 million, and 75 percent of its business is with the DoD. Then \$1 million will be allocated to all contracts and the DoD's share will be \$750,000.

In this report, only IR&D/B&P expenses up to the ceiling levels ought to be included in the overhead pool, because overceiling IR&D/B&P is ignored for defense contract costing.

The IR&D/B&P figure in Table E.2 includes *all* IR&D/B&P. McCullough and Balut (1990) do not break this down into underceiling and overceiling amounts. Alexander, Hillard, and Bodilly (1989) present this breakdown for the group of all major defense contractors.⁵ They report that in 1985 the ceiling level equalled 69.52 percent of the total level and this proportion is used in this report. Thus, it will be assumed that 30.48 percent of the IR&D/B&P expenses in

⁵Alexander, Hillard, and Bodilly (1989), p. 43.

Table E.3
The Result of Step 2

Cost Pool	Cost (\$ thousands)
Direct labor	1,737,766
Direct material	5,746,187
Overhead	3,580,964
G&A	650,006
IR&D/B&P	290,237
Material	279,222
M&E	2,361,499
Total	11,064,917

Table E.2 or \$127,280 is unallowable. Table E.3 displays the resulting figures when this amount is subtracted.

STEP 3: FACILITIES CAPITAL PROFIT

As explained in the report, DoD regulations break "economic cost" into two components. The first is labeled "cost" and basically corresponds to items an accountant would think of as costs. The second component is labeled "profit" and includes compensation for working capital, facilities capital, and risk bearing.⁶

Table E.3 includes only items from the first component. For all items of profit except that for facilities capital, this exclusion is of no great consequence, because the profit for each contract is directly calculated and no other costs are allocated based on these charges. Thus, they can be viewed as direct charges that do not receive any overhead allocation. Since they are not allocated themselves and do not affect the allocation process, they are irrelevant to the issues being analyzed here and will be ignored.

The one exception to this is profit for facilities capital. It is allocated across contracts using a base of direct labor and thus should be included as an overhead cost when calculating the magnitude of incentive effects. To explain this, it will be useful to provide a little more general background information on the process by which defense firms recognize facilities capital costs.

⁶See Rogerson (1991a) for a thorough description. The regulations governing profit calculations are in the *DFAR* 215.9 and *CAS* 414.

There are two issues. The first is how the costs of facilities are allocated to contracts. The second is how the costs of facilities are calculated. These will each be considered in turn.

First, regarding the method of allocation, most defense firms include all facilities capital costs as part of manufacturing overhead and allocate them according to direct labor usage along with all other manufacturing overhead.

Second, regarding the method for calculating facilities capital costs, three separate components are calculated. The first is depreciation. This is called a "cost" by the regulatory system and is included in Table E.3 as part of M&E overhead. The second component is called the "cost of money." This is the one major departure of government accounting conventions from commercial accounting conventions. A return to facilities capital is calculated by multiplying an interest rate called the Treasury Rate—an interest rate issued twice yearly by the Treasury Department—by the net book value of all assets. Its historic average is about 10 percent.⁷ This cost is formally labeled as a "cost" by government procurement regulations. However, it is not included in Table E.3 as part of M&E overhead. The third component is called "facilities capital profit." Just as for "cost of money" it is calculated by applying an interest rate to net book value. It is labeled as a "profit" instead of a "cost" and it is not included in Table E.3. This is no good reason for the separate existence of the second and third components and why one is labeled a cost and one is labeled a profit. This separation exists simply as a historical artifact determined by a series of separate legislative interventions.

From this report's perspective, the important point is that the second and third components are allocated according to direct labor. Thus, they are an overhead charge that firms can attempt to shift through manipulating direct labor. That is, conceptually, they are no different than any other element of M&E overhead. Therefore, they will be added to this overhead pool.

To do this, the typical or average value of these two components must be calculated. As reported above, the typical value for the Treasury Rate used to calculate the cost of money is 10 percent. Table E.4 summarizes the regulations that determine the interest rates used to calculate the facilities capital profit. Capital is broken down into three categories—land, buildings, and equipment. The regulations

⁷See Rogerson (1991a).

Table E.4
Interest Rates Used for Calculating
Facilities Capital Profit

Asset Type	Normal Value, %	Allowable, Range, %
Land	0	0 to 0
Buildings	15	10 to 20
Equipment	35	20 to 50

specify an allowable range and a normal value for the interest rate to be applied to each category. (As for cost of money, the interest rate is applied to net book value.)

McCullough and Balut (1990) report that in 1987 the net book value of assets for the four aerospace firms was \$2,205,500.⁸ Unfortunately they do not break this total down into the desired three categories. However, the last major DoD study of the defense industry, the *DFAIR* (DoD, 1985), provided such a breakdown for an extremely large sample of defense firms. Table E.5 reports the net book value of assets by each category as a percentage of the total net book value for 1983—the most current year of data contained in the *DFAIR* study. It will be assumed that the asset breakdown in Table E.5 applies to the four aerospace firms under consideration.

The value of the third component can now be calculated by multiplying a weighted average interest rate by the net book value of facilities

Table E.5
Net Book Value of Assets by
Category as a Percentage
of Total Net Book
Value of Assets

Asset Type	Percentage
Land	6.83
Buildings	35.33
Equipment	57.84

NOTE: 1983 data for all *DFAIR* firms. The data are from the *DFAIR* (DoD, 1985), Appendix 1, Volume II.

⁸Table 7, p. 19.

capital where the weighted average is constructed by averaging interest rates from Table E.4 using the weights in Table E.5. The only question regards which interest rates to use from Table E.4. The natural candidates are the "normal" values in the first column of Table E.4. However, on the basis of discussions with industry participants, it seems likely that (at least currently) the typical values used for calculations are lower than these normal values. The reason for this may be that before the last change in the regulations governing profit calculations in 1988, the interest rates applied to facilities capital were much lower. It seems that many contracting officers have not yet "accepted" the changes and tend to allow facilities capital profit somewhere between the value that would have existed under the old regulations and that which would occur under the new regulations.

This report will adopt the conservative approach of using the lower bounds of the allowable ranges to calculate the typical facilities capital profit. This results in a lower value of facilities capital profit than would occur if the normal values were used. This in turn means that the overhead rate is smaller and that the magnitude of the incentive effects is smaller, making it a conservative approach.

The resulting weighted average interest rate is 15.1 percent.⁹ Adding 10 percent for the cost of money component yields an interest rate of 25.1 percent.¹⁰ Applying this to the net book value of \$2,205,500 yields a return of \$553,581. Table E.6 adjusts Table E.3 by adding this amount to M&E overhead.

STEP 4: FRINGE BENEFITS

Fringe benefits for all employees, both direct and indirect, are classified as an indirect cost by the four aerospace firms. (This is typical industry practice.) All fringe benefits are part of the M&E overhead pool in Table E.6.

In this report's calculations, however, the fringe benefit costs of direct employees should be removed from the overhead pool and reclassified as direct, because they are a *linked cost* in the sense that expenditure of one more dollar on direct labor necessitates a certain additional expenditure on fringes as well.

⁹The corresponding interest rate is 25.5 percent using the normal values and 36.0 percent using the maximum values.

¹⁰The corresponding interest rate is 35.5 percent using the normal values and 46.0 percent using the maximum values.

Table E.6
The Result of Step 3

Cost Pool	Cost (\$ thousands)
Direct labor	1,737,766
Direct material	5,746,187
Overhead	4,134,545
G&A	650,006
IR&D/B&P	290,237
Material	279,222
M&E	2,915,080
Total	11,618,498

McCullough and Balut (1990) do not report fringe costs for direct employees separately. However, they give direct labor cost, indirect labor cost, and total fringe benefit cost. The approach that will be followed here is to assume that the fringe benefit costs are incurred for each employee group in proportion to the direct salary costs. This yields an imputed fringe benefit cost for direct labor of \$596,228. Table E.7 adjusts Table E.6 to reflect this by adding \$596,228 to direct labor and subtracting \$596,228 from M&E overhead.

Table E.7
The Result of Step 4

Cost Pool	Cost (\$ thousands)
Direct labor	2,333,994
Direct material	5,746,187
Overhead	3,538,317
G&A	650,006
IR&D/B&P	290,237
Material	279,222
M&E	2,318,852
Total	11,618,498

STEP 5: MATERIAL OVERHEAD

The material overhead pool is sufficiently small relative to its base of all direct material that it can safely be ignored without having any major effect. This produces a somewhat simpler set of formulas that are easier to interpret. Therefore, the material overhead will simply be viewed as part of direct material.

STEP 6: IR&D/B&P

Finally, since IR&D/B&P is allocated on the same base as G&A, it is mathematically equivalent to G&A for the purposes of calculations here. Therefore, it will be grouped as part of G&A. Table E.8 presents the results of Steps 5 and 6.

Table E.8
The Result of Steps 5 and 6

Cost Pool	Cost (\$ thousands)
Direct labor	2,333,994
Direct material	6,025,409
Overhead	3,259,095
G&A	940,243
M&E	2,318,852
Total	11,618,498

Appendix F

DERIVATION OF TABLE 5.4

This appendix derives overhead rates using data from Meyers et al. (1985) on the cost data initially proposed by contractors at the beginning of negotiations. The advantage of these data is that they are drawn from many more firms than are the McCullough and Balut (1990) data. However, the Meyers et al. data have two major problems. First, they are from contractors' proposals and are not actual *ex post* incurred cost data as is true for the McCullough and Balut (1990) data. Second, the summary of the cost breakdowns in Meyers et al. (1985) is not complete enough to perform all of the desired adjustments that were performed in Appendix E. Furthermore, there are some ambiguities in the description of the data which reduce the reliability of the estimates. Nonetheless, it is still of some value to show that the overhead rates calculated using these data are reasonably close to those calculated using the McCullough and Balut (1990) data.

Table F.1 presents the raw data from Table 2-4 of Meyers et al. (1985). Two points should be noted. First, these are the data for manufacturing contracts. Data were presented for three separate groups of contracts—manufacturing, R&D, and service contracts—but not for the entire group and not enough data were presented to allow construction of a weighted average. Second, 8.3 percent of the costs were labeled as "other costs" and it is not clear what these are. They were interpreted to be direct charges of some sort other than direct labor. Thus, mathematically, they are equivalent to direct material charges for the purposes of this report and they are included as part

Table F.1
Raw Data

Cost Pool	% of Total
Direct labor	19.8
Direct material	41.2
Overhead	38.9
G&A	12.7
M&E	26.2
Total	100.0

of direct material in Table F.1. This is, of course, a conservative procedure, since it minimizes the overhead rates. Third, material overhead is also included in direct labor.

STEP 1: FRINGE BENEFITS

The most important adjustment to make is to reclassify fringe benefits for direct labor as a direct cost. No data are supplied on the magnitude of these costs. Therefore, it will be assumed that the ratio of fringe benefits to salary costs is the same as for the McCullough and Balut (1990) data. There, fringes equalled 34.31 percent of salary costs. This means that 6.8 (0.3431×19.8) percentage points should be moved from M&E overhead to direct labor. Table F.2 presents the result of this calculation.

Table F.2
The Result of Step 1

Cost Pool	% of Total
Direct labor	26.6
Direct material	41.2
Overhead	34.4
G&A	12.7
M&E	19.4
Total	100.0

STEP 2: FACILITIES CAPITAL PROFIT

Just as in McCullough and Balut, the data in Table F.2 do not include the cost of money or facilities capital profit. Meyers et al. (1985) report that the net book value of facilities capital equalled 10.4 percent of the total costs. Applying the same weighted average interest rate as used in Appendix E of 25.1 percent thus yields a return to facilities capital of 2.6 percent (25.1×0.104) of total cost. Adding 2.6 percentage points to the M&E pool and recalculating all percentages so the total still sums to 100 yields Table F.3. The overhead rates in Table 5.4 are calculated from Table F.3.

Table F.3
The Result of Step 2

Cost Pool	% of Total
Direct labor	26.0
Direct material	40.2
Overhead	33.9
G&A	12.4
M&E	21.5
Total	100.0

Appendix G

DERIVATION OF TABLE 7.1

Table G.1 presents the raw data from McCullough and Balut (1990), where total overhead is broken down into a number of separate components. As usual all of the data are in thousands of 1987 dollars. The data will now be transformed in five steps. The rationale for most of these steps was described in Appendix E and will not be repeated here. Only new considerations that did not arise in Appendix E will be discussed.

Table G.1
Raw Data

Cost Pool	Cost (\$ thousands)
Indirect labor	926,212
Fringe benefits	968,643
Facilities related	610,841
Data processing	396,679
Corporate office allocation	163,186
IR&D/B&P	199,118
Others	443,565
TotalF	3,708,244

STEP 1: FULLY LOADED IR&D/B&P

Appendix E calculates that \$218,399 of M&E overhead is allocated to IR&D/B&P. The raw data in Table G.1 do not distinguish between M&E overhead and G&A overhead. Corporate office allocations are entirely in G&A. All other categories contain both G&A and M&E overhead. In the absence of any better method, it will be assumed that the \$218,399 of overhead is drawn proportionately from all of the cost categories except corporate office allocation. Subtracting the calculated amounts from each of the categories and adding \$218,399 to IR&D/B&P yields Table G.2.

Table G.2
The Result of Step 1

Cost Pool	Cost (\$ thousands)
Indirect labor	865,756
Fringe benefits	905,417
Facilities related	570,970
Data processing	370,787
Corporate office allocation	163,186
IR&D/B&P	417,517
Others	414,611
Total	3,708,244

STEP 2: ALLOWABLE IR&D/B&P

As calculated in Appendix E, \$127,280 of IR&D/B&P expenses are unallowable and must, therefore, be subtracted.

STEP 3: RETURN TO FACILITIES CAPITAL

As calculated in Appendix E, a return to capital of \$553,581 must be added to the facilities' related costs.

STEP 4: FRINGE BENEFITS

As calculated in Appendix E, \$596,228 of fringe benefits apply to direct labor and thus should be removed from overhead. The remaining fringes apply to indirect labor and will be considered part of indirect labor. Table G.3 presents the results of Steps 2-4.

Table G.3
The Result of Steps 2-4

Cost Pool	Cost (\$ thousands)
Indirect labor	1,174,945
Facilities related	1,124,551
Data processing	370,787
Corporate office allocation	163,186
IR&D/B&P	290,237
Others	414,611
Total	3,538,317

STEP 5

The data in Table G.3 include M&E, G&A, IR&D/B&P, and material handling overhead. The IR&D/B&P is separately identified and can be subtracted. From Appendix E, G&A expenses total \$650,006 and material handling overhead expenses total \$279,222. It is clear that the corporate office allocation of \$163,186 is part of G&A. This leaves net expenses of \$486,820 which must be subtracted from Table G.3 to yield M&E overhead. In the absence of actual data on the cost breakdown of G&A and material handling, it will be assumed that these pools are drawn proportionately from all cost categories except facilities' related. (Most facilities are probably part of M&E overhead.)

Prorating \$486,820 over the cost categories and subtracting the resulting values, subtracting the corporate office allocation, and subtracting IR&D/B&P yields the result presented in Table G.4.

Table G.4
The Result of Step 5

Cost Pool	Cost (\$ thousands)
Indirect labor	715,812
Facilities related	1,124,551
Data processing	225,895
Others	252,594
Total	2,318,852

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